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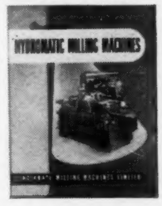
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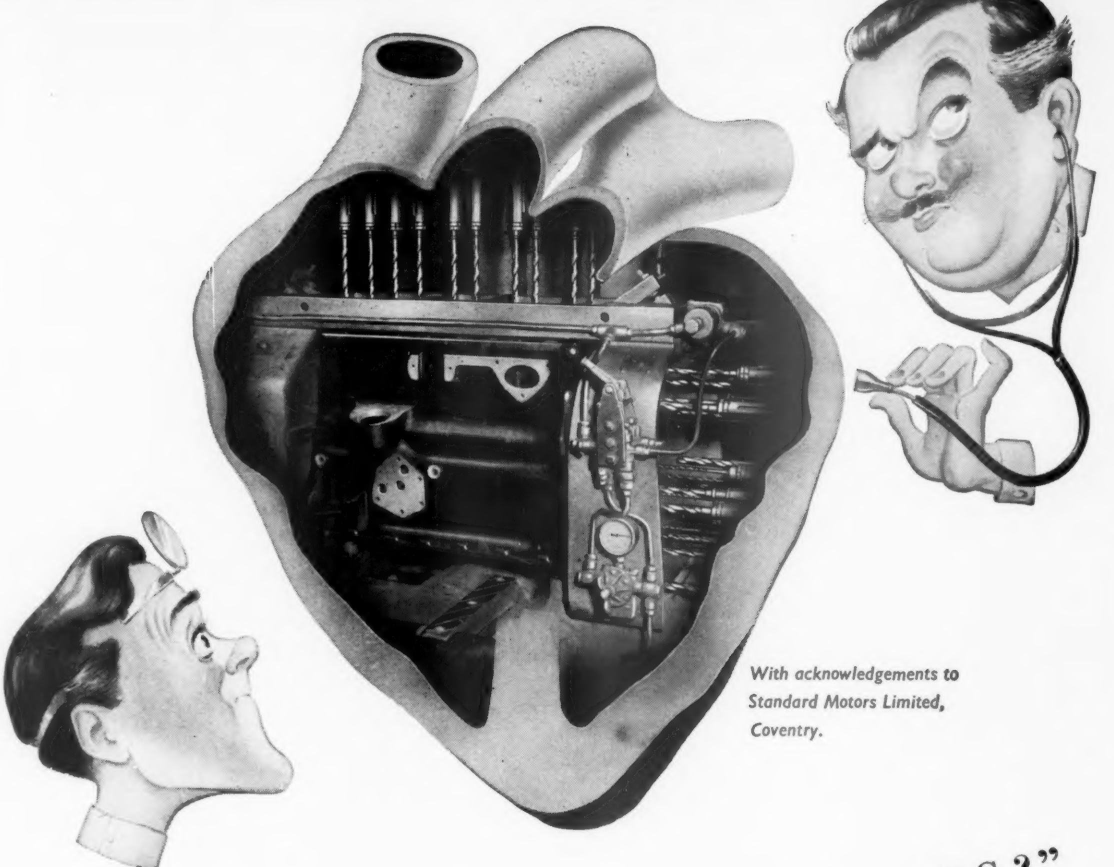

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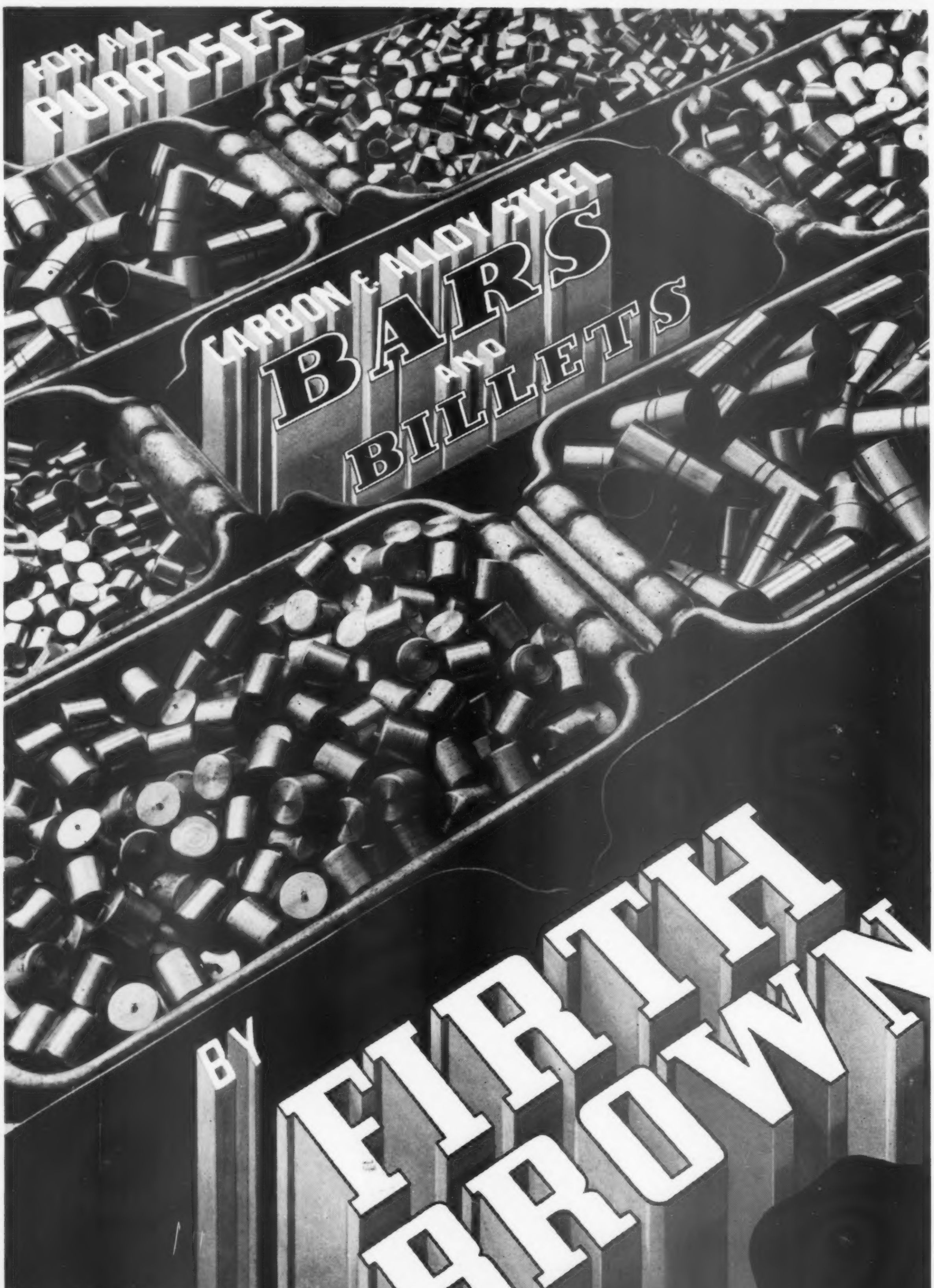
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The Institution of Production Engineers Journal
VOL. 33 NO. 11 NOVEMBER, 1954

Education and Research for Production

It had been intended to publish in this issue the first contribution to the new series of leading articles introduced last month by the Chairman of the Editorial Committee. However, in the three addresses at the Institution's Annual Dinner such apposite references were made to the theme of the series that it has been decided to include the relevant passages as a contribution.

SIR Walter Puckey, President of the Institution, during his speech in which he proposed the health of the guests, said:

"What was the subject of greatest concern to me during last year? From many I would select that ever-increasing gap between the demand for production and allied technologists and the limited supply of them. Whether you study the Institution's employment bulletin, the advertisement columns of lay and technical press, the latest Colombo Plan report, or the personal requests so many of us receive, the evidence shows that we appear to lack the skilled technologist-power required to record adequate progress in our research, development and production programmes. Government and industry are asked to allocate more capital to new technologies and new plant, but money isn't our real problem—it is men to spend it wisely.

Dividing the Problem

"We are tending to divide this problem of technologist-power into two parts, short-and long-term. Dealing with the last first, we hope that the various plans to expand technical college and university facilities will ultimately produce the quality and quantity required. Certainly enough working parties have sat and received evidence, but I do not think that clear solutions have yet emerged. I, for one, believe that technical colleges and universities are not too sure of their long-term objectives, and we may wait a long time before they can satisfy our needs for technicians and technologists.

"One thing on which we have to be clear is the sort of men we want to steer Britain's industry. Many say that we want more scientists, but fail to define the word. Is the production engineer or manager a scientist? Whatever your definition I say with the greatest emphasis that unless we provide a balanced group of skilled manpower we shall fail. The creative spark emitted occasionally by a Newton, a Rutherford or a Whittle will not in itself provide light, heat and power to the world, just as the spark plug is of no value on its own, but only when assembled with other components.

"We British are supposed to be better creators than producers, and this charge will always be fairly made until we realise fully that it is not enough to have only a product research or even a design programme. Unless we at the same time initiate a production, and indeed other programmes too, such as sales, we shall fail to reap what we have sown.

"I am here as a spokesman for the production engineer whose scope extends from work study to works direction and above. His job is important and becoming more so, but I would do him a disservice if I suggested it was the only important task. Many production engineers are being promoted

to senior managers, where they find that the secret of industrial success is to be sure that the spark produces maximum effect, by the balanced effort of the whole industrial power unit.

" This shortage of technological manpower will not be cured only by taking men from other spheres, which themselves must play a part in Britain's ultimate success. Skill is a universal shortage and, to give an example, only last month the President of the Chartered Insurance Institute, widely removed from ours, said that recruitment was their greatest single problem. Other bodies tell the same story.

Importance of Delegation

" Can better education help us? It can if it brings out more of that potential value which lies untapped in most of us. It can if it shows us that good organisation means more delegation of those things we needn't do, so that we are more free to do those things we are better fitted to do. Why, if every executive delegated to a deputy half-a-dozen more jobs a week, how much potential skill would be brought to the surface! Let us make a list of jobs we regularly do and see how many have become routine, and therefore unworthy of our time and skill.

" Let us, descending to a lower level, have more " one-ulcer " men doing a " two-ulcer " man's job, and wear our own worried look on the face of our deputy.

" There are other ways of using our skills more effectively. Sir Harry Pilkington, President of the F.B.I., said recently that co-operation in research programmes would save manpower. Perhaps he might agree, however, that we must save skill on other jobs as well as in research. However, all co-operation is grand as long as it doesn't blunt competition.

" And now to someone we would have been delighted to have with us tonight. Sir Ronald Weeks is no stranger to us. A few years ago he did us the honour of speaking at one of our Conferences, and we have heard much about him from many of his executives who are leading members of this Institution. His career is a remarkable one, and any man who started in industry, became a Deputy Chief of the Imperial Staff and then, rejoining industry reached the position of great eminence Sir Ronald now holds, deserves our deepest respect."

In the absense of Sir Ronald Weeks through illness, his address was read by Lord Sempill, a Past President of the Institution. After saying he intended to touch on national matters and then refer specifically to technical education, Sir Ronald's address continued:

AT the moment there appears to be a wealth of confidence in our industrial programme, certainly a much greater confidence than I personally expected 12 months ago. Every day reflects this position on the Stock Exchange, in Wall Street, in the City, in better company results, in larger dividends; all this alongside a condition in world affairs which, in spite of several recent bright spots, is quite appalling in its threat to our future.

" The Chancellor makes his moves with a clarity and courage for which I, for one, have the greatest admiration. He has not achieved his early goal of convertibility, but if he slips back an odd rung, there is no doubt that he is steadily climbing towards his objective.

" We rail against the administration of directors' expenses, against taxation both for ourselves and our companies; quite rightly we want more carrots for company expansion and for the benefit of management; and in saying that I am not arguing against improved conditions for our partners in enterprise, our workpeople, provided they are earned.

" As far as we are all personally concerned and because, as I said six years ago at one of your Conferences, and I now repeat, " we specialise in manufacture and are dependent on the markets of the world ", all aspects of productivity are our vital problem. The fact that we are improving is only a stimulus to a desire to improve faster.

Increasing the Tempo

" All these things are on the asset side of our national balance sheet and yet without being by any means a pessimist, I am somewhat apprehensive, because the tempo of our improvement is not fast enough.

" Can I put the other side of the picture :

1. our gold and dollar reserves, though improved, are not adequate;
2. we cannot decrease our imports further without lowering our standard of living;

3. our internal and external debt is increasing;
4. competition in our overseas markets is intensified;
5. the spiral of wage increases continues.

"There are, of course, several remedies required to improve our national economy, but I will only deal with one, and that is, improved productivity.

"If my information is correct we have improved to the extent of 3% per annum for the last five years, America over the same period $3\frac{1}{2}$%, and Germany 16%, though in the latter case it would be fairer to compare the years of 1952 and 1953, which show $4\frac{1}{2}$% per annum.

"Anyway, our own rate of improvement is not good enough. American wages are over three times larger than ours, yet their productivity per manhour is so high that in many things they can compete with us abroad. America is more production-minded than we are yet and she has more production equipment available for her workers, and this is being added to faster than we are doing.

"However attractive in theory it may be to have complete convertibility, I feel that it is too much oxygen to administer at the present moment, and I hope we shall move in a series of steps to achieve this highly desirable condition of affairs; in fact, speaking for myself, I don't want to give up at too quick a rate the overcoat of protection in our ability to export either to America or to markets where there is a dollar shortage, but I am willing if the sun will shine and if we work to deserve it to change the overcoat for a raincoat and finally to shed a coat altogether.

"I would like to pay tribute to the work of the Anglo-American Productivity Council and to the British Council of Productivity.

"There is no doubt whatever that both employers and employees are more production-minded; it is also true that Trade Union leaders are approaching the problem in a statesmanlike manner. A lot of new and constructive thinking is going on; Lord Bruce voiced some outspoken and imaginative suggestions when he addressed the Finance Corporation for Industry last week.

Education for Research

"I know I am on common ground with you all in stressing the importance of the productivity problem, though in this short address it is too big a subject for me to cover adequately.

"The multitude of the facets include:

(a) research;
(b) application of research;
(c) every form of technology, including your own;
(d) management;
(e) finance;
(f) salesmanship;
(g) removal of restrictive practices, whether by Government, employers or employees;
(h) education for research, technologists and technicians.

"You will notice that I put education last on my list, but certainly not last in importance, and it is on this I would like to talk a little more fully in my capacity as Chairman of the National Advisory Council for Technical Education for Industry and Commerce.

"It is notorious that education is a subject on which almost as much heat can be engendered as by an atomic pile or by an Australian Test Match; it is something on which everyone will express a view whether they know anything about it or not, and it is a subject on which the universities, technical colleges, local authorities, industry, the institutions, the Government, never quite see eye to eye either with each other or even within their own specific ranks.

"Some people will argue that the university is not the place to teach higher technology; some will argue that technical colleges are a waste of time except for technicians; these are the extreme views. It is therefore with some diffidence that I approach this thorny subject, but it is nevertheless one of the most important factors affecting both the national and your own development.

"A university's principal function is to train young men who after obtaining further experience will eventually become technologists, but on top of that we pay tribute to the contribution universities make to research and in the last few years the universities have developed and are increasing facilities in new post-graduate courses of technology.

"Her Majesty's Government have already made a tentative announcement on the creation of additional technological facilities. I believe in all these trends.

"The policy as regards the future of technical colleges is slightly more obscure. Some people will say that the chief obstacle to progress is the fact that the technical colleges are provided for and owe

allegiance to the local educational authorities. Frankly, I do not believe this is true. Education is often a local question, industry is local; in many cases the Board of Governors are given a large element of freedom.

The Vital Needs

" The National Advisory Council proposed in 1950 a Royal College of Technology and made various recommendations. Some were accepted, but the name and the award were not. We were asked to think again on the basis that an award of national currency was desirable. We have thought again and proposals have been sent to the Minister. I cannot give you the details of these proposals, but I can give you the line of reasoning which inspired them :-

(a) the need to develop high level courses in technology which, in common with the aims of this Institution, have a direct industrial application;
(b) the need for an improvement in equipment and accommodation in the technical colleges and conditions of service for teachers;
(c) the need to attract students by providing a national award which would quickly acquire recognition, and this calls for a national body to moderate the courses and grant awards.

" We do not believe that the best way to improve conditions immediately is arbitarily to pick out a certain limited number of large colleges, free them from association with their local education authorities (assuming this can be done) and say here and here alone, shall higher technological work be carried on. This is a solution which appeals to the tidy planners, but it is not one which is in the line with the hard facts of the present situation.

" There are certainly large colleges which may be expected to bear a substantial share in the developments which we have in mind, but there are also much smaller colleges in certain areas, such as Stoke (for ceramics) and Camborne (for metalliferous mining), where work of a high standard is carried on in one particular department, or where in such a subject even as engineering close associations with local industry have combined to produce an unique course of high quality, and these colleges must be encouraged to develop and improve.

" It should be remembered that technical colleges have their roots in local industry and one of their chief responsibilities is to educate the part-time students at whatever level is required. It would be impracticable to expect a few colleges only to cater for all these part-time students.

A National Award

" Not only, however, must there be new courses and conditions. We believe that the technical colleges will not fill their true role in future developments unless concurrently steps are taken to provide for students successfully completing the courses an award of national standing, which shall not gain its prestige from association with existing university titles, but which shall be separate and distinct. providing alternative forms of education to university courses, and their standards guaranteed by a national body of high standing in the work of which industry, the professional institutions, the universities and the technical colleges will all be asked to co-operate.

" I do not dispute the desirability of certain technical colleges emerging in due course as technical universities—they may; but the object of the National Advisory Council is speed in getting something moving which does not in the slightest degree cut across such developments, or in fact cut across any of the well-established objectives of many of the important bodies represented here tonight.

" Many of us are groping as to the type of course which will fill our respective requirements, whether it can be done at universities, or technical colleges (in which I include national colleges such as Cranfield). Sir Hugh Beaver, with his analysis of what facilities now exist in management and corelated studies, must be getting some way in evaluating the real needs.

" Lord Halsbury analysed your own position, Mr. President, as regards courses in his recent very able speech when he gave the 1954 Sir Alfred Herbert Paper, in which he laid the blame on the employer for the poor attendance at the few available courses in Production Engineering Technology. He may be right, but the very fact that several large industrial concerns find it essential to provide training facilities of their own is in itself an indicator that the development of very source of training is required.

" The fact that we are still short of high grade technologists is recognised by everyone, but in spite of the existing and proposed facilities I have a suspicion, which is shared by others, that what we need *in addition* is a post-graduate technological establishment which will take the very best (and I mean very best) qualified people, (who in addition to their scientific training will have a period of works experience) and will turn them out as practical high grade technologists; men who would, to use

(concluded on page 651)

MODERN GEAR PRODUCTION

by H. J. WATSON, B.Sc.(Eng)., A.M.I.Mech.E.,

Presented to the Manchester Section of the Institution, 26th April, 1954.

Mr. Watson

Mr. Watson was educated at the Wintringham Secondary School, Grimsby, and University College, Nottingham. He received his practical training with Ruston & Hornsby, Limited, Lincoln, and J. S. Doig, Limited, Grimsby.

He joined David Brown & Sons, Limited, Park Gear Works, Huddersfield, in the Research Department in 1929 and, subsequently, held the positions of Research Engineer, Technical Engineer and Assistant Chief Engineer. He took up his present appointment as Head of the Research and Development Department, Park Gear Works, in 1951.

DURING the past few years the amount of published information of all kinds relating to toothed gearing has been considerable. Much of the technique of gear production is widely known, but improvements in design and manufacturing technique are constantly being made. To meet a requirement for information relating to some of these later aspects, an idea of the fundamental principles underlying the various types of gear in general use and the usual methods in vogue for their production, is not out of place.

For many applications, there is a decided trend towards determining a more nearly correct estimation of the real duty requirements and this is permitting gear manufacturers to make their products suitable for ratings which are known with a greater degree of certainty than has previously been feasible. Such gears, by working nearer to their designed capacity, benefit in performance and in many cases smaller and more economical gear drives have resulted. On the other hand, to attain the best results in such circumstances accuracy of the finished gear has had to be increased and the story of modern gear development has largely run in that direction.

Types of Gears

Gears are broadly divided into two groups: those connecting parallel shafts and those connecting non-parallel shafts.

In the former group the simplest are spur gears, in which the tooth flanks are parallel to the shaft axes. They have a natural characteristic when running, insofar that when made with standard proportions one pair of teeth in contact alternates with two pairs, imparting fluctuating stresses and deflections to the teeth. This has some influence on their application and performance since, although theoretically they transmit uniform velocity, the fluctuating tooth deflections tend to cause noisy running at high speeds and where noise is of serious consequence, the maximum permissible speed is usually limited. One widely applied method of mitigating the effects of

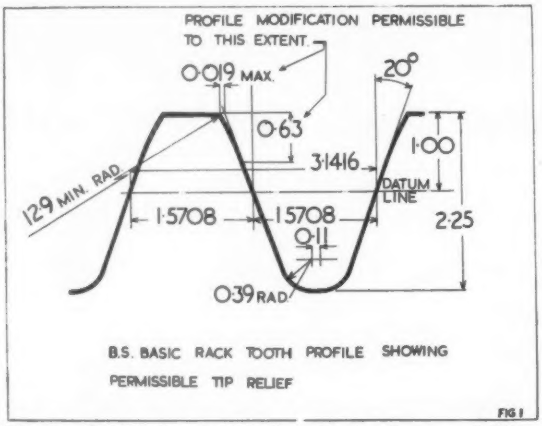


Fig. 1. British Standard basic rack showing permissible tip relief.

deflection is the application of tip or root relief, sometimes both, whereby a smoother engagement is effected and shock is prevented (Fig. 1).

No such feature affects the second type of parallel shaft gears. In this group, the tooth flanks occupy spiral positions relative to the shaft axes and for correct odontographic congruity, the spiral angle at the pitch cylinder on one gear must be equal in magnitude to that on the conjugate member, but of opposite hand. Such gears are known as helical gears and may consist of one, two or three alternately handed helices across the face-width of a gear (Fig. 2).

Helical gears embody the highest form of the gear-maker's art and the most accurate gears made fall within this category. Because practically a constant length of line of contact can be maintained for all stages of engagement, difficulties associated with fluctuating tooth deflection are largely eliminated, and helical gears can be run at very high pitch line speeds provided continuity of action is ensured by designing the teeth for overlap of contact.

Single helical gears necessitate provision for carrying the unbalanced axial thrust on each member of a gear pair, and usually the helix angle is selected to be a minimum compatible with overlap to reduce end thrust to manageable dimensions. Double helical gears are self-contained with regard to end thrust and no external thrust-absorbing device is required.

Triple helical gears were chiefly used for mine winding in South Africa. Although there were three helices, the end thrusts were balanced across the face-width and they behaved in the same way as double helical gears. In recent years this type has tended to become obsolete, largely owing to the high cost of production, and the advantages claimed for it have been shown to be fallacious.

Spiral or skew gears are used to connect shafts whose axes lie in parallel planes but are not parallel to themselves (Fig. 3). Each gear of a pair is essentially a single helical gear and the sum of the helix angles is equal to the shaft angle required; they need not necessarily be of opposite hand. They make contact at a point only and consequently have a low load carrying capacity.

Where shaft axes intersect and lie in the same plane bevel gears are used (Fig. 4). They can make any desired angle between the shafts but the most usual is a right angle. Both straight and spiral teeth are used and the gears are known as straight or spiral bevels respectively, having tooth actions essentially similar to those of spur and helical parallel shaft gears.

A variant of the spiral bevel gear, introduced as a production type in America about 30 years ago, is the hypoid gear, in which the shaft axes lie in parallel

Fig. 2. Typical examples of planed helical gears in double reduction rolling mill drive.

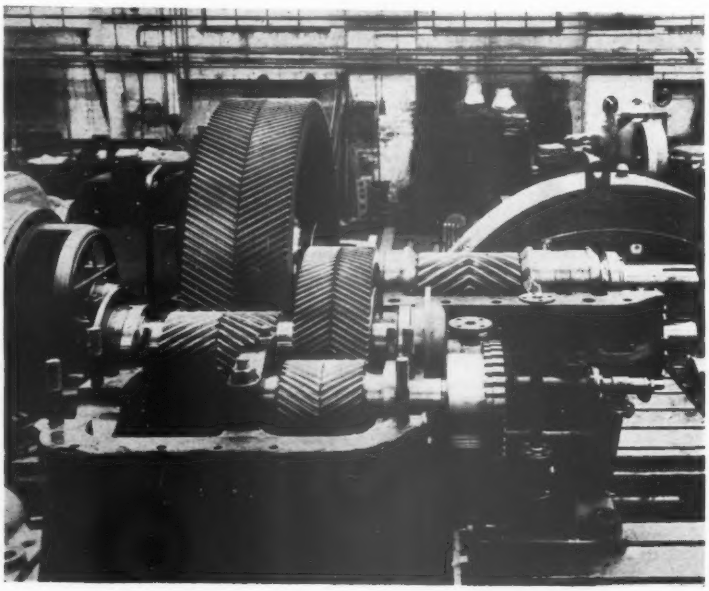


Fig. 3. Spiral gears for automobile speedometer drive. The material combination is bronze and casehardened steel.

planes but do not intersect. The amount of offset of one axial plane relative to the other is usually not more than about one-fifth of the cone distance and, because of it, an axial sliding component is introduced in addition to the normal rolling and sliding action of spiral bevels.

Finally, worm gears (Fig. 5) are also used to connect shafts in parallel planes whose axes do not intersect. They are the most versatile of all gears because of the wide range of ratios which may be employed for the same centre distance. A shaft angle of 90° is usually employed, but other angles may be used to fulfil special requirements. Worm gears fall into two main groups: those employing a parallel worm, which is a single helical gear of large spiral angle, and those made with an " hour-glass " shaped worm or double-enveloping worm gears.

The former is the easier type to make and parallel worms can be case-hardened and profile ground to impart a high degree of accuracy to both thread form and lead angle. " Hour-glass " worms are not normally profile ground and are usually made from through-hardened steel. Considerably more work is required in their manufacture and although some designs are capable of greater load carrying than the more straight-forward type their production is commonly regarded as uneconomic except for special applications.

General Introduction to Gear Production

Toothed gears are made at the present time largely following the same general methods in vogue at the beginning of the century. At that time machine cutting had been firmly established as a means of production, but moulding, and particularly machine moulding, of gear teeth was extensively applied. The emphasis now is overwhelmingly in favour of the former method, but the latter is by no means obsolete and many gears are still manufactured by casting teeth directly into the gear blanks.

Dealing with cast teeth first, it is true to say that, except for small gears produced by some of the newer methods, the accuracy of the product is inferior to that obtained from cutting the teeth. Large gears cast in iron, steel or bronze, with no subsequent finishing process applied to the teeth, inevitably suffer from the distortion produced by unequal stresses introduced during cooling. Founders, of course, take precautions and exercise particular care to ensure that errors are kept within acceptable bounds, but the fact remains that compared with the equivalent machine-cut gear, deviation from the true tooth form, pitch and concentricity are considerably greater.

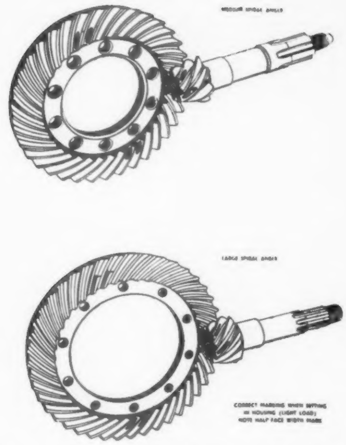


Fig. 4. Line drawings of typical automobile spiral bevel gears, showing the desirable no-load contact marking.

Cast gears, however, have their applications and usefulness. They are often of large size and pitch and are generally slow moving where the effect of errors is not of supreme importance. Their cost of production is lower than that of their machine-cut counterparts and the hard skin formed on the tooth flanks is usually particularly resistant to abrasive wear. Well-made cast gears will accommodate themselves to considerable abuse in mounting and often give good service over many years.

With the advent of the lost wax or investment process of casting, accuracy of a high order can be obtained and although the process is much more costly than sand moulding, its accuracy, added to wear resistance, makes production economical for some applications.

Fig. 5. Rear axle worm gears.

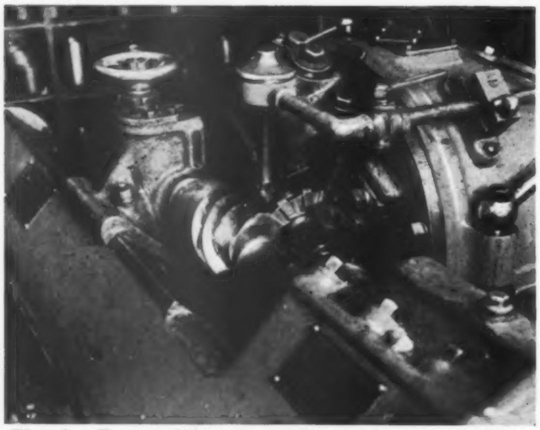


Fig. 6. Form milling worm threads in worm milling machine.

Fig. 7. End milling rolling mill pinion.

Sintered powder metallurgy, die casting, precision casting and moulded plastics are further modern means of gear production which have their fields of application and are tending to be increasingly used where their advantages and limitations are recognised.

When considering cut gears, there are four methods in use to-day and each has its utility and peculiarities. The oldest and the least applicable to modern ideas of production is form milling in which a single rotary milling cutter removes metal to form tooth spaces. This process depends essentially for its effectiveness upon the accuracy of the milling cutter profiles. Each space is cut separately and succeeding teeth are cut by indexing around the gear blank. It is often inaccurate and consequently, except for the manufacture of very large pitched gears, it has been largely superseded by faster and more accurate processes.

Two types of cutter are used, the circular milling cutter and the end mill. The former is mostly used for large spur gears and the latter for helical gears of which winder gears and rolling mill pinions are examples. Circular milling cutters are still favoured for heavy stock removal on large pitched gears destined to be finished by a more accurate method such as planing, but their most extensive use is for the rough cutting of worms which will subsequently be case-hardened and profile ground (Fig. 6). For the latter purpose, a cutter profile has to be designed to take into account potential interference from the helical thread form and to provide an approximately constant grinding allowance.

End milling cutters are designed to give the correct tooth profile (Fig. 7). Unfortunately, they are subject to wear which tends to modify their shape, and errors in tooth form result towards the end of a pass prior to correction of the cutter by regrinding. This necessitates recourse to hand dressing when a pair of end-milled gears are meshed together and is a costly process.

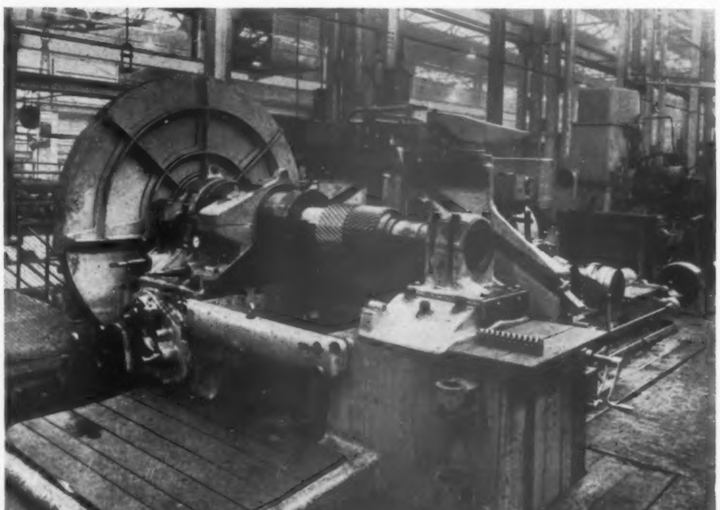


Fig. 8. Planing double helical pinion with rack type helical cutters in gear planing machine. Note additional cutters on side of machine.

A second method of production extensively used is planing with a rack type cutter (Fig. 8). This is a true generating process in which the gear blank is uniformly rotated about its axis while the cutter, made with straight-sided cutting edges, is simultaneously advanced in the direction of its length at the same speed as that of the pitch cylinder of the blank. This imparts a relative rolling motion between the gear and the cutter and, in order to provide cutting action, the cutter is caused to reciprocate across the face of the gear coincident with its longitudinal translation. An advance of a distance of just over one pitch is arranged for the cutter before rotation of the blank is arrested, the cutter is then returned to its starting point and the cycle is repeated until the blank has completed one revolution. The gear is formed by sinking the cutter deeper for succeeding cuts until full depth is attained. The number of roughing cuts necessary to generate the teeth fully depends upon the pitch, but usually not fewer than two are made, followed by a finishing cut.

The planing process is applicable to both spur and helical gears. For the latter, the cutter teeth are inclined and the cutter is reciprocated in a direction parallel to the helix angle of the gear. Double helical gear planing machines employ two rack cutters operating alternatively on each helix, each cutter travelling half-way across the face. Continuous-tooth double helical gears necessitate accurate setting of the cutter travel, so that each cutter in turn removes the " flash " at the end of its stroke by slightly over-running into the opposite flank. About 0.010" to 0.015" additional travel is sufficient to achieve this object without damage to the work. When possible, it is more usual to provide a gap between the two helices and this practice has the added advantage of preventing oil trapping when the gears are run with apex trailing.

The Gear Shaper Method

A process very extensively applied in gear production is that known as the gear shaper method, in which the cutter is similar to a pinion provided with cutting edges. The gear blank and the cutter are each given rotary motions about their respective axes such that if they were completed gears, they would roll together at the correct centre distance. Simultaneously the cutter is reciprocated across the face-width of the gear blank and by feeding the cutter radially into the blank, involute teeth of full depth are generated having the same pressure angle as that of the cutter on the pitch circle of generation.

Gear shaping lends itself to the sucessful manufacture of both external and internal toothed gears although in the latter case, the size of cutter must be so selected that for 20° pressure angle, a tooth difference between work and cutter of fewer than 8 should not be used if trochoidal interference is to be avoided and part of the involute profile destroyed.

Two makes of machine are in general use. The older Fellows type (Fig. 9) uses a vertically reciprocating cutter with the work mounted on a horizontal table and by providing a cutter with single helical teeth which reciprocates in a corresponding helical path, single helical external or internal gears can be cut.

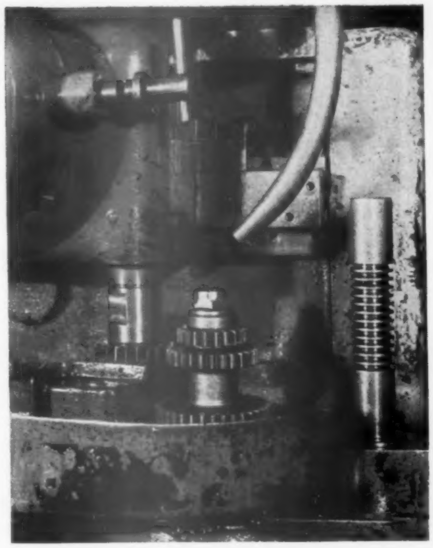


Fig. 9. Cutting spur cluster gear by the Fellows gear shaping process.

The newer or Sykes machine (Fig. 10) requires the work to be mounted with its axis horizontal and the cutter reciprocates horizontally. This machine can be fitted with two horizontally opposed cutter guides, in which each cutter in turn advances on its cutting stroke while the other is being withdrawn in preparation for its next working stroke. By using right and left-handed helical guides, double helical gears can be produced.

Both gear shaping methods have an advantage over the gear planing process in that the work is continuously rotated. The cutters can also be produced with a greater measure of pitch accuracy than

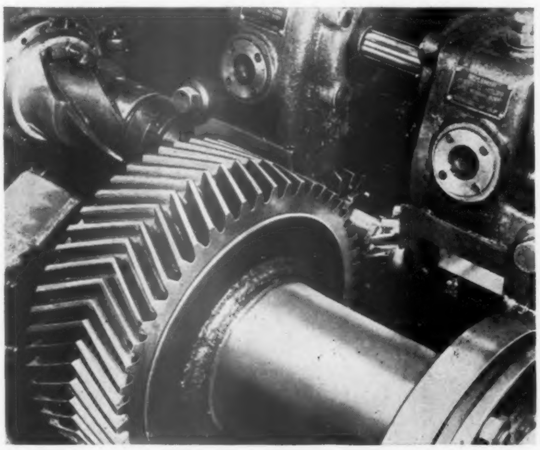


Fig. 10. Generating continuous tooth double helical gear by Sykes gear shaping process.

the simpler rack form and the work consequently benefits by reason of smaller adjacent and accumulated pitch errors.

Gear type cutters, however, unlike the rack cutter which possesses the feature of retaining its tooth form unaltered by repeated sharpening, change their shape with successive sharpening. To provide the necessary cutting rake the profile of a cutter tooth changes on each successive plane lying normal to the axis. Every part of the profile, however, on succeeding parallel planes involves the involute to the same base cylinder, with the result that although the cutter may appear to vary in pressure angle as its thickness is reduced, it will continue to generate identical gears.

Hobbing is regarded as the most accurate of the methods employed in gear cutting and more thought and care have probably been lavished on hobbing machines and their functioning than on any other type of gear generator. During the past few years, considerable advances have been made in improving the accuracy of hobbed gears and benefits from the large expenditure of time and effort on the process are beginning to accrue, but in spite of the marked improvement in accuracy of profile, helix and pitch, there is still a long way to go.

In principle hobbing is fundamentally quite a simple process. The gear blank and the hob mesh together when spur or helical gears are being cut, as a pair of spiral gears in which the hob is the pinion (Fig. 11). Usually the hob consists of a single thread, gashed and relieved to form teeth with cutting edges.

During operation the hob is mounted on a spindle oriented at a suitable angle to mesh with the teeth of the work piece when they are cut. The work and hob are then caused to rotate with uniform motion and in inverse ratio to the number of teeth on the work and threads on the hob. Cutting is effected by feeding the hob radially into the blank to the depth of cut required and traversing it gradually across the face of the gear in a direction parallel to the axis of the work. Since the hob is one member of a pair of spiral gears, it makes a series of point contacts with the work and cutting proceeds as the envelope of the series of contact points is formed. The extent to which this generated envelope approximates to a true involute depends upon the number of teeth or

Fig. 11. Hobbing spur gear.

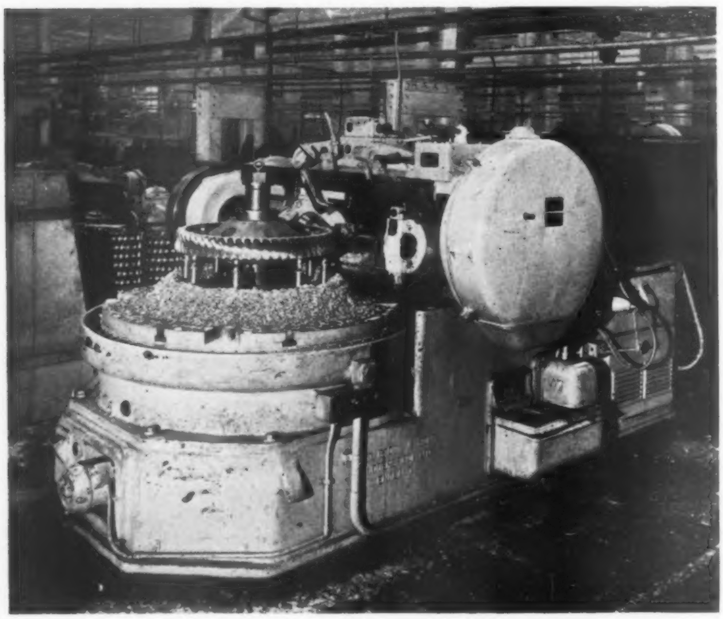


Fig.12 Hobbing industrial wormwheel on wormwheel generator.

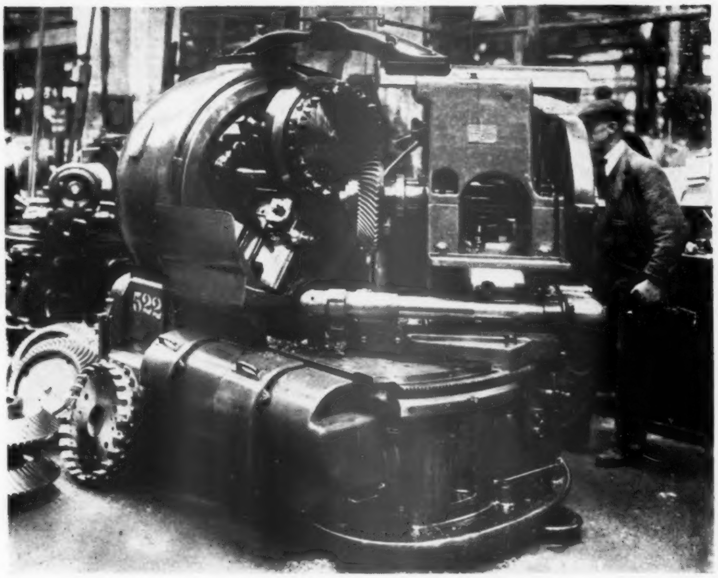


Fig. 13 Curved tooth (Gleason) spiral bevel gear in course of generation.

gashes in the hob and the distance the hob traverses across the face of the blank with each revolution of the work. The continuous rolling of the gear while in mesh with the cutting teeth of the hob ensures that every tooth on the work is progressively generated.

When cutting helical gears, in addition to the above motions the hob or work is given a further motion equal to the advancement or retardation, which the hob would have rolled if it had been meshing with a stationary gear.

Hobs are manufactured as precision tools of the highest attainable degree of accuracy to suit the work being cut. The British Standard Specification 2062:1953, recently published, lays down the dimensions and permissible errors in three Grades, A, B, and D for general purpose hobs and accuracy requirements for Grade AA turbine gear hobs.

Worm wheels are normally generated by hobbing (Fig. 12) and the process is similar to that employed for cutting spur, spiral or helical gears although there are some important differences. The hob itself corresponds closely with the worm which will eventually mesh with the wheel, but the hob threads, instead of being continuous as with a worm, are gashed and relieved to form cutting edges. In this hobbing process two methods are available. In the first, the hob is fed radially into the work to the correct cutting depth, while in the second, simultaneously with the infeed, a tangential feed is imparted to the hob in the direction of the axis of the hob which coincides with the axis of the worm or, as a cutting refinement to improve contact conditions, the axes of hob and worm make a small angle with one another. The latter is known as "swing" cutting for which the hob is made rather larger than the worm, but of the same normal pitch and normal pressure angle, so that the hob and worm have lead angles differing by the amount of "swing."

The hob and work are given relative rotations about their respective axes with speeds corresponding to the ratio of the finished gears. In practice, the hob is made to move in a direction opposite to that of the work and to effect this, the rotary motions of the hob and work are geared to the hob traversing motion to impart to the hob one more revolution than would be required by the ratio in the same time that the hob is traversed one lead to compensate for axial movement of the hob equal to the lead.

If the ratio of the number of threads in a multi-start hob and the teeth in the wheel being cut is a whole number, some spacing errors may result. For this reason, wherever possible, it is preferable to design gears with a hunting tooth since indexing errors are thereby eliminated and, in some instances, the wheel is cut with a hob having one more thread than the worm.

Further cutting processes which should be mentioned are those applicable to bevel gears. These are similar in principle to the method used for the production of spur and helical gears, although in this case the generating process is modified to suit the rolling motions of two pitch cones instead of pitch cylinders.

Before dealing with generating processes, however, one rapid modern method of form milling for straight bevel gears may be briefly touched upon. This is the Gleason Revacycle process, in which a large diameter disc cutter, fitted with blades projecting radially from the periphery, completely cuts one tooth space with each revolution of the cutter. A space between the starting and finishing blades permits the work to be indexed while the cutter continues to rotate at a uniform rate. It is a useful manufacturing process for quantity production of straight bevels and is extensively employed in the production of differential bevel gears and similar types.

Of the generating processes perhaps the most interesting is that employed in cutting spiral bevel gears (Fig. 13) and the Gleason method, because of its widespread use, is a suitable subject for consideration. In this the tooth spirals conform to circular arcs and the form of the cutters and their motion sweep out the tooth profiles of the basic crown wheel with which the work piece is imagined to be in contact. Generation of the tooth profiles is obtained by giving to the work a rolling motion relative to the cutter, similar to that the finished gear would have when engaging with the crown wheel.

Modern Developments in Gear Production

The foregoing outline of the methods employed in the manufacture of toothed gearing can naturally be extended to include a comprehensive description of any or all of the recognised modern gear production processes, from the choice of material to the finished article. Possibly it will be of interest, however, to examine the manufacturing processes applied to two or three representative types of modern gearing.

Automobile Gearbox Gears

From the nature of their application automobile gearbox gears are heavily loaded, and in a box of conventional design this is particularly true of the layshaft driving gears, which are loaded for all indirect gear conditions and the first or second speed gears, whichever pair is required to work for any appreciable length of time. The complementary requirements of this type of gear drive are that dimensions shall be as small as possible in conformity with the duty, and that weight shall be a minimum, and they influence extensively both the design and manufacturing methods employed. Modern conceptions regarding allowable loading for an acceptable length of life have permitted such gears to be designed with adequate load-carrying capability, but with a smaller surplus capacity than was generally regarded as desirable some few years ago. This has resulted in a tendency towards the use of somewhat smaller gears for the same engine torque, provided manufacturing techniques are evolved compatible with theoretical considerations.

The finished gear depends for its performance as much upon the material used as on any subsequent work done on the blank. This is by no means a new idea, but experience has shown that in these days of material shortages the selection of the correct steel has a profound influence on serviceability. The majority of gearbox gears are case-hardened using stamped blanks, the amount of work done on the blank being such as to cause the natural grain flow of the metal to be oriented radially. Prototype sample upset stampings are first produced using various shapes and sizes of billet. These are cut up and deep etched and the method of forming the blank with the best grain flow is chosen for bulk supplies. Grain size is not necessarily as important with double quenched work, as when single quenching is used, because both case and core are refined in the former process, but it is preferable to use fine grain steel when possible and a McQuaid Ehn grain size of 6/8 is usually specified.

With the conventional En. 35, En. 36 or En. 39 steels, using normal double quenching methods, satisfactory service can be obtained. An essential requirement is that gearbox gears shall be resistant to bending fatigue or shock loading rather than to surface fatigue, and such steels can usually be relied upon to provide it. They seem to tolerate a certain amount of deviation from the ideal heat treatment, such as that found in normal manufacture, without any appreciable reduction in strength. On the other hand, the " lean " steels of the En. 352, 353 and 355 types, which are regarded as substitutes for the richer alloys, are less tolerant to variations in heat treatment and a reduction in strength of about 15% can be obtained with ordinary treatment. Constant mesh gears, however, do not appear to give trouble when made from substitute steels, but clash engagement, perhaps the effect of high speed shock, can cause trouble.

En. 352 seems to be appreciably more sensitive to heat treatment than En. 36, but, to be impartial, if the ideal treatment can be accorded to the former, there is little difference between them.

Owing to this degree of uncertainty, some manufacturers of automotive gearbox gears are tending to revert to the use of the higher alloy steels for their production in those instances where a change in design to accommodate the possible lower load-carrying capacity of the lean steels is impossible.

For cutting the teeth either gear shaping or hobbing is used; which process is used depends, of course, upon the availability of gear cutting plant, but since teeth in their cut condition are not in their final usable state, they must at least be suitable for a satisfactory finishing process insofar as accuracy of profile, helix angle and spacing are concerned.

Multi-start Hobs

Considering hobbing, the application of multi-start hobs has latterly been used to speed up production and a few general points may perhaps profitably be examined. The hob itself, whether of the single or multi-start type, must be made to a very high standard of accuracy, particularly the profile and spacing of the gashes or " teeth." Spacing is of exceptional importance in hobs with more than one start, since errors between the helices are directly reproduced on the hobbed gear.

In setting up the hob on its arbor the hob must run truly about its axis, within about 0.0005" for the best work, and in fastening it on the arbor a nut provided with plain locating sleeves on each side of the thread is useful in preventing bending of the arbor. When length of a hob is sufficient, it is advisable so to position it that the active teeth will lie towards one end and when wear renders further use of these teeth impracticable, a further set of teeth can be utilised by moving the hob axially relative to the work, thus permitting longer working life between grinds. It is not considered good practice to permit the maximum worn land on a hob tooth to exceed about 0.015" to 0.020" before re-sharpening.

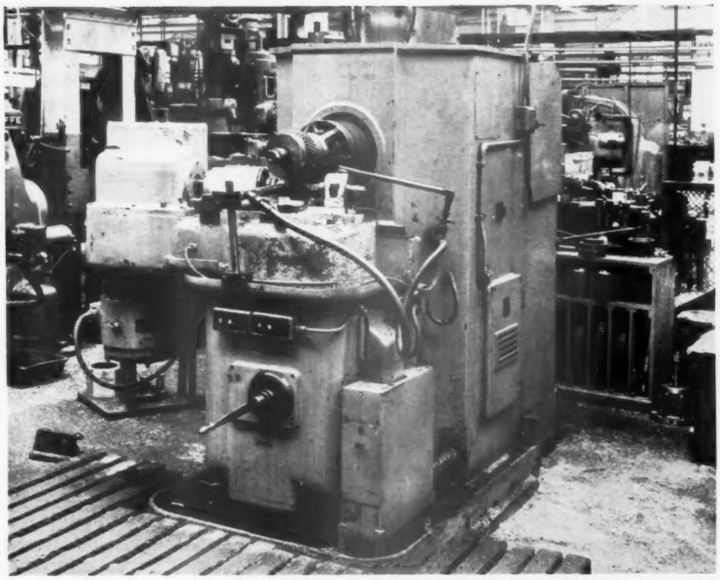


Fig. 14. Heavy duty high speed hobbing machine cutting automotive gearbox gear.

The hobbing process is such that only one tooth in each thread cuts to the full tooth depth in the work; consequently it suffers the most wear, although the teeth on either side of it are worn to only a slightly less extent. Accordingly, this implies that a two-thread hob is likely to have an advantage over a single-thread hob, although owing to the impracticability of making both types with equal accuracy, some loss in accuracy inevitably results from the use of a multi-start hob.

It must be realised, however, that for a specified cutting speed a two-start hob requires the hobbing machine table to rotate twice as fast as when a single-start hob of the same diameter is used, and the hobbing machine must be capable of accommodating the increased speed. In practice, the full advantage of the increased speed is not usually realised, since in order to obtain a length of life between grinds with a two-start hob equal to that of one having a single-thread, the feed per revolution of the work is usually smaller with the former type and the ultimate advantage is less than two to one.

Not all gearbox gears can be cut with two-start hobs and differences in size of gear, pitch, depth of cut permissible and other factors may make normal single-start hobbing preferable in many cases.

One major improvement in automotive gearbox gear manufacture which has come into prominence within the past few years has been the application of higher cutting speeds for hobbing. The idea is not new and fundamental work on the question of cutting speeds was commenced about twelve years ago, and has been continually pursued since then using accurately made fly cutters operating in a horizontal milling machine to simulate hob teeth. These were caused to machine 0.5% carbon steel billets, normalised to have a tensile strength of about 47 tons per square inch, about 18″ long and 4″ square, in a longitudinal direction using climb-cutting and controlled depths of cut, rates of feed and cutting speeds. Measurements of the amount of wear on the cutting edges were constantly made and each test was terminated when a worn land reached an arbitrarily determined value of 0.0005″. The total length of metal removed was recorded and observations made of surface finish.

As the tests progressed it became clear that the results were useful for comparing machineability of different materials, the properties of cutting fluids and the effect of cutting speeds. The normal cutting speeds in use were shown to be much too low for optimum tool life and surface finish, but when attempts were made to increase them in actual practice it quickly became apparent that the hobbing machines in normal use were unsuitable for any really appreciably higher running speed.

To utilise the potential advantages shown by the investigation much more rigid and robust hobbing machines were necessary and such machines have now been designed and made. A prototype hobber is shown in Fig. 14 which is used for regular production work cutting En. 36 steel gears at 250 feet per minute with 0.050″ feed. Other models of this machine have since been further developed to be capable of attaining 1,000 feet per minute.

Production times have been spectacularly reduced by increased cutting speeds and, in some cases, tool life has been lengthened with no deterioration in surface finish or tooth shape.

In all gear cutting, it is essential to bear in mind that the most influential single item affecting the finished product is truth of running about its designed axis. An investigation undertaken about a year or so ago, to determine the causes of operational difficulties in a prototype automobile synchromesh gearbox, revealed that the most prolific source of the trouble lay in eccentric running and "wobble" in the individual gears. All the preliminary thought and planning put into ensuring gears running true to within a few tenths of a thousandth of an inch are usually amply rewarded.

Heat treatment of automotive gearbox gears can affect performance to a marked extent. After hob-

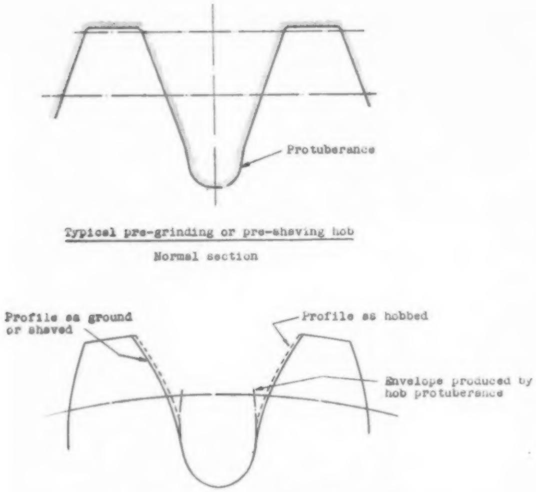


Fig. 15. Protruberance hob.

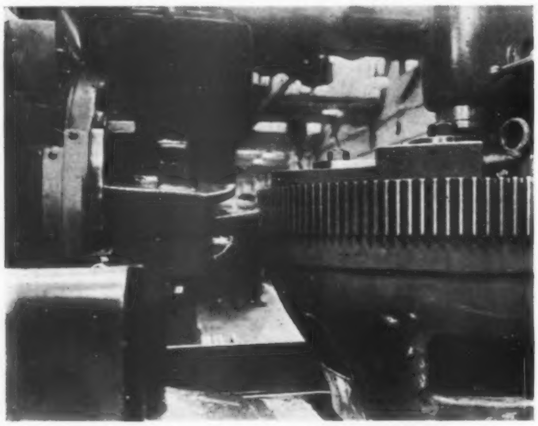


Fig. 16. Spur gear being shaved.

bing it is usual to carburise those parts of a gear required to be hard, such as the teeth and engaging clutches. If parts are to be left soft, the uncut blank is copper-plated so that when teeth are cut the tooth flanks are exposed to the action of carburising gases. For pack carburising a deposit of acid copper about 0.002/3″ thick on a preliminary " flash " of nickel is an effective stopping agent, but for the more penetrating action of the gas carburising process, the denser deposit given by a cyanide copper " flash " followed by 0.002″ of acid copper is necessary if unwanted hardening is not to result.

Gas carburising is becoming more extensively applied to automotive gearbox gears and has certain technical advantages over the older pack method, of which perhaps the more important are cleanliness of the work surfaces, a better control of carbon gradient and prevention of high carbon concentration at corners.

When teeth are not to be profile ground, shaving is an excellent method of finishing them and provides perhaps an ideal production method of correcting errors resulting from the cutting process. It is used after hobbing and before hardening. The use of a protuberance type hob or cutter (Fig. 15) is to be preferred for generating the tooth flanks, since the slight undercut provides clearance for the tip of the shaving cutter and avoids the dangerous stress-raising step which normally results if a conventional cutter be used.

Shaving is essentially a finishing process and must not be regarded as an additional cutting process. It is necessary, therefore, for the cut gear to have only small errors in pitch, profile and concentricity, since shaving will improve a good gear, but will not convert a bad gear into a good one. At production rates of gear cutting, both general tooth accuracy and surface finish leave some room for improvement and shaving provides a relatively quick and easy means of imparting the desired tooth form, including tip and end relief if required, and rectifying small spacing errors.

The Shaving Cutter

The shaving cutter is essentially a spur or helical gear, provided with serrated teeth in which the serrations lie in planes normal to the cutter axis. The axes of the work and cutter are not parallel (Fig. 16) and selection of the crossed axis angle affects the rate of cutting and the resultant finish of the work. Generally, the smaller the angle, the smaller the amount of metal removed, the finer the finish, and the most satisfactory value is about 15°. Owing to the orientation of the axes, the work and cutter act as spiral gears and make point contact, assuming the surfaces are geometrically accurate and are not deformed by load. Under the imposed shaving load, however, this point becomes an area elliptical in form by deformation of the work material with the major axis much longer than the minor axis.

When such simulated spiral gears rotate together in mesh, sliding takes place at every point of contact and the action of the cutting edges is such that fine shavings of metal are scraped off the surfaces of the work. The nearer these are to geometrical precision, the less favourable are the conditions for cutting, because each cutting edge is made with zero relief and only very high localised pressure will permit sufficient surface deformation to enable the edge to cut. Gears direct from production hobbing have tooth profiles sufficiently deviating from the required form to make shaving a practical finishing process and its application to automobile gearbox gears produces a high standard of accuracy.

Under working conditions, the high tooth loading of automotive gearbox gears produces deflection in both teeth and shafts. There is a certain amount of controversy about the need for tip or root relief in helical gears to compensate for tooth deflection, but since face-width is usually small compared with diameter for this class of work, end relief alone is not generally considered sufficient and a small amount of tip relief may be beneficial, that is, not more than a few tenths of a thousandth of an inch. A large amount of tip relief for helical gears is detrimental to their load-carrying capabilities since it has the effect of stubbing the teeth. This may have some advantage

in resistance to tooth breakage but it reduces opposition to wear. For instance, with heat treated carbon steel helical gears the difference in running life for approximately the same degree of surface deterioration between excessively corrected and uncorrected teeth, under identical running conditions, has been found as high as about 5 or 6 to 1. For gears disposed on a shaft about midway between the supporting bearings, little effect from shaft deflection is evidenced by heavy end markings, but for gears situated in other positions, alleviation of this undesirable contact condition may be obtained by barrel-shaving, whereby the ends of teeth are made progressively thinner than the middle. Such barrelling should not exceed two- or three-tenths of a thousandth.

Hardening of the case and refining of the case and core are carried out in the usual manner followed by tempering. The case after hardening should have a hardness value lying between 61 and 63 Rockwell C. Tempering is a very important operation and significantly affects future performance of an automotive gearbox gear. Static tests to determine the breaking load of En. 36 steel gear teeth have shown that as the tempering temperature is increased from 125°C. to 200°C., the strength increases up to a maximum at about 170°C./180°C. and then falls.

One of the service troubles encountered with end engaging gears and clutches is chipping of the case in spite of the most careful rounding; this can be mitigated to a great extent by flame tempering these local surfaces. It results in some slight loss in hardness to about 57 Rockwell C., but service performance fully justifies its application.

Automobile Rear Axle Spiral Bevels

Here again the importance of the correct material and stampings for the blanks cannot be over-emphasised. Most spiral bevels and hypoids produced in this country are made from stampings, and it seems to be a regrettable fact that sufficient care in selecting the correct grade and size of billet for stamping is not always exercised. The enforced use of substitute steels, often of undesirable grain size, is a contributory factor in producing finished gears which are not always up to the desired standard.

Ideally, the billets used for a batch of spiral bevel gears should be gauged by " go " and " not go " gauges to ensure close control of size, grain flow and adequate work done on the blank. Blanks themselves should be gauged to determine size and concentricity; an eccentric blank implies variation in material density with resulting uneven reaction to heat treatment in the finished gear. This inevitably leads to contact difficulties.

Another factor which must be most carefully controlled is the initial normalising of the blanks. After the stamping operation, this is perhaps the most important insurance of future success, because the subsequent cutting and the effect of hardening are substantially affected by the condition of the blank material.

In manufacture a useful modern innovation has been the employment of a copying lathe for turning the pinion blanks and this has undoubtedly led to a greater dimensional consistency in the turned blank, combined with reduction in turning times when dealing with batch work, but the multi-tool lathe is still of most use for quantity production.

Mounting the Blanks

Mounting the blanks for cutting to ensure correct support on the cutting arbors entails careful dimensional control of locating diameters. This is not always easy to effect, because a reasonable tolerance must be provided for the locating diameters, yet the blank must not be tight in the cutting arbor nor so easy that, particularly in the case of a wheel, the teeth are cut eccentric to the axis. With a wheel of 7" diameter, the tolerance between the cutting bore and its arbor must not exceed 0.0014", for example.

Teeth are rough cut and finish cut as two separate operations and for subsequent convenience wheels are made " standard," or in other words, all adjustment for tooth shape to compensate for distortion of both members during hardening and deflection under load is confined to the pinion.

Reducing distortion in the wheel during heat treatment is one aspect of bevel and hypoid gear manufacture which has always received particular attention, but improvements in quenching dies are always under consideration. It is necessary to hold the ring as nearly circular as possible and the back face flat to within two or three thousandths of an inch without restricting the flow of cooling oil to the teeth. A resulting slightly hollow back face is preferable to one which is humped or perfectly flat, because it ensures that contact will be clear of the heel end of the teeth under no-load conditions. It is necessary to take precautions against the adhesion of foreign matter to bevel wheel rings while in the hardening furnace, and heating them on a rigid rack or grid is sometimes useful.

For correct contact conditions it is usually necessary to make a number of experimental pinions, to determine how much unwinding of the tooth spiral may be expected during hardening. Compensating modifications to the tooth profile and spiral are then made when cutting production pinions. Deflection under load is largely controlled by the mounting of the gears and unless maximum rigidity in the gear housing is provided, considerable difficulty in obtaining an adequate tooth bearing area may result, which no amount of cutting skill can overcome. Under maximum torque conditions, deflection should not exceed about 0.003".

Importance of Rigidity

In recent years, the need for rigidity both in the gear case and in the gears themselves has been increasingly realised and with a general stiffening of the mounting, it has been found possible to lengthen the no-load contact with some advantage in load-carrying capacity and trouble-free running. For the highest standard of rigidity, the wheel section should be a ring of as deep a section as conveniently possible and supported on a carrier of maximum stiffness. It is sometimes possible to reduce the overall weight and size of an automotive bevel gear driving unit by using smaller yet more rigid gears to deal with a

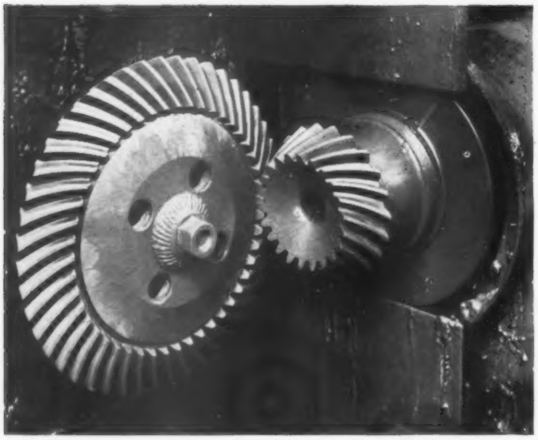


Fig. 17. Spiral bevel gears in course of being lapped in bevel lapping machine. The abrasive is suspended in oil and pumped into the mesh.

given torque. This result is perhaps more clearly demonstrated with hypoid gears, where the pinion offset results in a larger diameter of pinion than with spiral bevels of the same ratio and crown wheel diameter.

If adequate control is exercised throughout the manufacture of spiral bevels and hypoids up to the final running-in, this last operation should be a quick finishing process, solely used to polish the tooth flanks (Fig. 17). Lapping should not be regarded as a means for correcting errors acquired during previous operations although in exceptional circumstances some improvement in meshing of the gear pair may be obtained by lapping for more than the ideal length of time; excessive lapping almost invariably results in the destruction of the tooth form otherwise so laboriously obtained. Even the largest gears should be capable of being finished satisfactorily by final lapping within 15 minutes, and for smaller motor car gears 3 or 4 minutes is usually adequate, particularly for hypoids where the sliding action between the teeth naturally assists lapping. Automatic lapping has recently been introduced with considerable success for quantity production, but this emphasises the need for the highest degree of accuracy in gears up to that stage.

A further modern development in the production of spiral bevels and hypoids has been the introduction of a chemical phosphating process to the teeth. The most usual is a proprietary process known as Parco-lubrising, which attacks the tooth surfaces to a limited extent. The net result is a slight increase in tooth thickness of something less than 0.001″, which can easily be accommodated. The function of such a finish appears to be the provision of a surface which assists bedding-in. Tests carried out on hypoid differential units in a power circulator showed that scuffing could be produced at will on untreated teeth when the extreme pressure additive in the lubricating oil had been used up, but with Parco-lubrised teeth, however, new gears were found to be immune from scuffing, even when lubricated with a straight mineral oil. The use of such oil for hypoid gears is, of course, not advocated for service conditions, but the tests indicated the benefits of phosphating as a bedding-in agent.

Marine Main Propulsion Gears

Probably no other type of gear attains to the same high standard of accuracy as marine gears, in spite of their size, and within recent years considerable advances have been made in their production with a view to increasing accuracy still further.

They are produced in the first instance by hobbing on machines essentially designed and built for producing turbine gears which are themselves instruments of extremely high precision. Owing to the size of the work involved the machines are necessarily large and some idea of the requirements demanded are given in the British Standards Specification No. 1498/1948 wherein two degrees of accuracy, Grades "A" and "B" are laid down. The standards of accuracy are both higher than was considered either necessary or attainable only a few years ago.

Owing to the length of time required to cut a main propulsion wheel, variations in ambient temperature were found to be a source of appreciable error, and one of the essential modern innovations has been the introduction of temperature-controlled buildings to house the gear-cutting plant. Temperature is controlled between ± 1°F. and has been found effective in eliminating the daily bands.

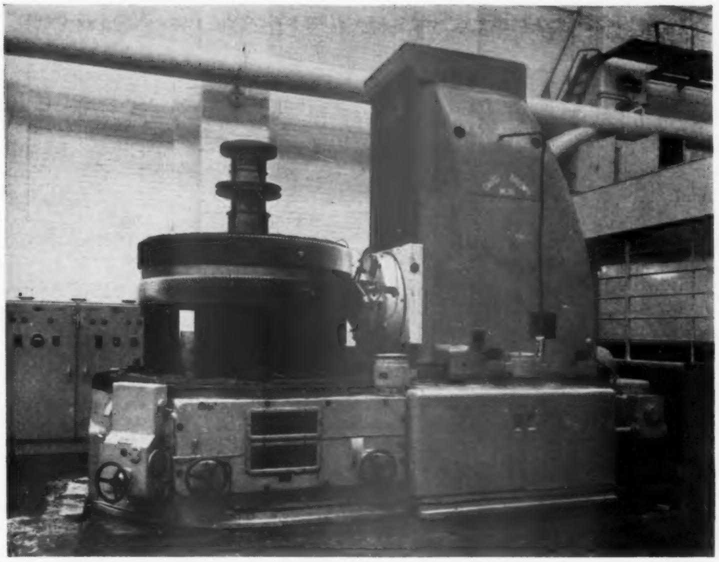
Control of the shop temperature alone has not been the whole story in overcoming the effects of temperature changes, since simply by running a large hobbing machine unequal expansion occurs which is sufficient to introduce inaccuracies into the various motions, and before cutting a gear it is often necessary to run the machine light for some length of time, sometimes as long as 40 hours, to obtain thermal balance.

Importance of Foundations

An essential requirement for all gear-cutting machines is maximum rigidity and the latest examples are the embodiment of stiffness (Fig. 18). Further, no gear-generating machine is better than its foundations and considerable care has been expended in providing really solid structures on which to support the mass. Even with the best foundations some deflection is perhaps inevitable, but it must be uniform and maintain the table and head relatively perpendicular to one another. There is some difference of opinion about the need to insulate a foundation from its surroundings, but this largely depends upon the nature of the ground and a machine shop built on a solid rock foundation is truly fortunate.

One of the most effective contributions to accuracy of tooth spacing introduced within recent years has been the provision of highly accurate main table driving gears, which have done much towards eliminating periodic undulations in the tooth spirals. These were previously a prolific source of trouble in service, since they tended to promote noise and vibration and introduced a risk of scuffing on the

Fig. 18. Turbine gear wheel in course of being cut on 100-inch hobbing machine.



crests of the undulations present along the tooth spirals, particularly in gears cut on non-creep machines.

Improvement in dynamic balancing has contributed in no small degree to the better running of modern turbine gears, and with the expected introduction of pinion speeds up to 20,000 revolutions per minute, balance will become even more important. With a pinion speed of 10,000 r.p.m. out-of-balance on the pinion should not exceed 2.7 gm. at 5" radius and for a wheel running at 1,500 r.p.m. the corresponding values are 1.7 gm. and 10".

Since the end of the War, materials from which marine gears are made have been receiving considerable attention, mainly with a view to reducing size and weight for the same power transmitted. The medium carbon steel wheel and nickel steel pinion which have been in use for some years generally gave satisfactory service. They possess the useful property of accommodating themselves to errors in contact and alignment by permitting a small amount of plastic deformation during bedding-in. This has tended to protect teeth from breakage due to bending fatigue at the roots, while at the same time work-hardening increased resistance to pitting when such gears were gradually run in. Contact and alignment errors had to be reasonably small, otherwise stress concentrations could, and in some cases did, cause trouble, particularly by scuffing. Experience with heavily loaded gears in Naval vessels did, in fact, demonstrate that such materials have definite limitations to what errors can be accommodated and examples of both scuffing and tooth breakage occurred.

The present trend is directed towards the use of materials capable of being heat treated to tonnages of about 60 to 75, as compared with the previous range of 32 to 45. Such steels, however, are even more sensitive to meshing errors and their use has only been made possible by the recent considerable increase in manufacturing accuracy.

A further trend involves the use of case-hardening steels for both wheel and pinion and some highly successful experimental gears have indicated that

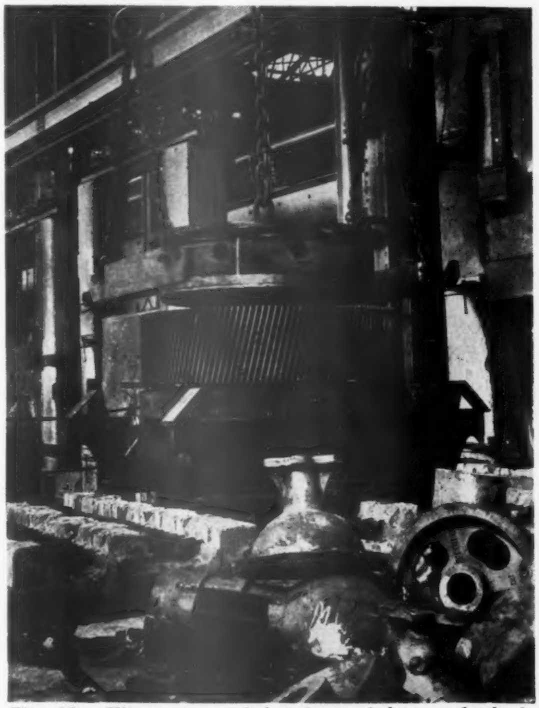


Fig. 19. Wheel centre being lowered into carburised turbine wheel rim, 71-inch diameter, prior to quenching. The rim is supported on set-screw heads carried in a heat-resisting steel frame.

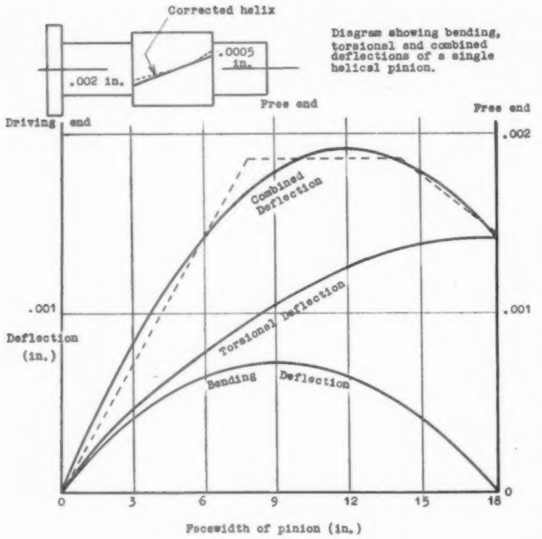


Fig. 20. Pinion deflections.

such materials possess considerable potentialities (Fig. 19). Heat treatment technique, however, calls for a high degree of skill and care in planning and execution, but further experience is needed before case-hardening can be extensively applied, although the success so far achieved is probably indicative of the future. Two major difficulties are experienced by distortion and diametral growth during heat treatment of large wheels which consist of a rim shrunk on to a centre. The tackle supporting such a ring in the furnace must maintain the shape of the ring uninfluenced by the furnace floor, and it must also ensure control within a few thousandths of an inch during quenching. The best method of dealing with dimensional growth is still rather uncertain, but running centres may, of course, be increased to compensate for the larger wheel diameter.

Owing to distortion difficulties always present in case-hardened gears, and the need for post-hardening profile grinding of the teeth, some consideration has been given to the application of a nitriding steel to marine main propulsion gears. By the use of such material, the gears may be finished before heat treatment and the nitriding temperature of 500°C. is not expected to result in distortion, provided the preliminary heat treatment necessary before the teeth are finished is successfully carried out. Earlier experience with nitriding steels was not always successful owing to the tendency for the case to crack and flake. Whether later steels of D.T.D. 551 type will be immune remains to be proved, but theoretically they should at least be better.

A further advance which has been successfully applied to marine main propulsion gears within the past few years has been the correction of pinions to compensate for deflection under load (Fig. 20). The idea of correcting the tooth spirals to permit a more even distribution of load when the pinion is distorted by torque and load deflection is by no means new, and has been regularly applied to heavily stressed traction gears of all types for many years, but only recently has manufacturing accuracy of marine gears attained a sufficiently high standard to permit the successful application and measurement of such a refinement. Two deflections occur simultaneously on the loaded flanks, one caused by the distribution of load across the face of the gear when it is regarded as a simply supported beam, and the other by twist when torque is applied to one end. The amount of compensation needed is complicated by variations in load during service, but by making correction suit the full designed power condition, concentration of load at the torqued end can be prevented. No means of correction can be perfect and practical considerations necessitate further compromises, but as an example, in one particular instance modifying the helix angle over half the face-width by about 0.0002″ per inch length has been found adequate.

Before leaving marine main propulsion gears, mention should be made of a departure from more orthodox types introduced by the employment of epicyclic units for this purpose during the past few years. Successful application up to the present time has been limited to units transmitting relatively small powers for such use, but the large variety of possible designs and their small space requirements even for large horsepowers, compared with more orthodox gear arrangements, with the possible exception of those employing case-hardened gears, makes the use of epicyclic marine gears a probable future development. From the production point of view, they are at least as difficult to manufacture as the most complicated locked-train units made at present and call for the highest standards of accuracy in gear cutting and in mounting the gears. Such difficulties as exist, however, can be overcome by the exercise of present-day skills and technique.

Finishing Processes Applied to Gears

The finish of gear teeth has received a great deal of attention during post-war years and the work expended in improving it has met with some degree of success. In hobbing, perhaps the most marked advance has been accomplished by improvements to hobbing machines and this applies not only to new machines, but also to older machines which have been rebuilt to meet the accuracy exacted by present-day requirements. Even the standards of accuracy laid down in the present British Standard Specification 1498/1948 Grade "A," mentioned earlier, are tending to be inadequate and are being revised although they are extremely difficult to meet.

One of the most important improvements has been that made in the design of the table worm wheel for large hobbing machines, where the number of teeth has been increased to between 600 and 1,000 using a long tooth and a small pressure angle of 10°. This ensures that a minimum number of 5 teeth is always in contact and the effects of errors in the wheel itself are smoothed out. Undulation errors along the tooth spirals have been either eliminated entirely or so reduced in magnitude that they can be removed by one pass of a shaving cutter.

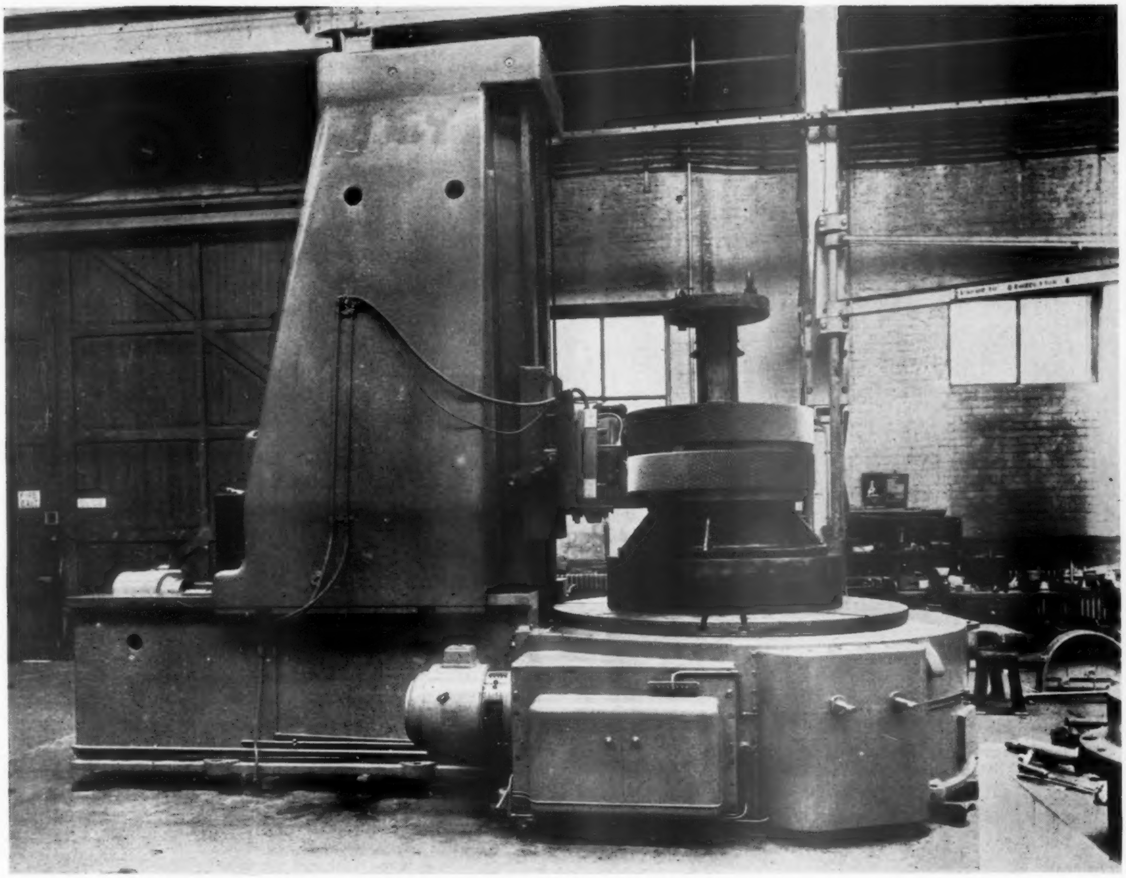


Fig. 21. Shaving marine turbine gear on 100-inch shaving machine.

However, the support given to the hob in the hob saddle is a very real element in modern hobbing technique and the advantages of extremely rigid mounting have not by any means yet been fully exploited. Preferably, the hob should be carried on a stiff arbor and the practice of many marine gear manufacturers is to use an arbor not less than 2.25″ in diameter. Wherever possible, the hob should be built up and profile ground on its arbor and in the machine it should be carried in bearings located on either side of the cutting tool itself, if possible utilising the arbor as journals. A run-out not exceeding 0.0002/3″ on the hub or registering diameter is essential for the highest class of work.

This apparent obsession for ever-increasing accuracy in gear manufacture can largely, but by no means entirely, be attributed to a desire to reduce noise in operation to the absolute minimum. Users of toothed gearing have been becoming increasingly noise-conscious over a number of years and, in many instances, those members of the population affected by the emission of gear noise have played no small part in the demand for quieter gear drives. The more widespread employment of mechanically-driven road transport, for instance, has been a vigorous element in the pursuit of quieter gears.

To generalise, certain types of toothed gearing, such as spurs or straight bevels, by the nature of their contact have only limited potentialities for quiet running, but other types such as helical gears and spiral bevels are much more amenable to improvement. If all other conditions remain the same, the largest single characteristic affecting gear noise has been found to be accuracy, accuracy of tooth spacing, concentricity, balance and tooth profile, to mention some of the most important, and any improvement in accuracy bears fruit in a reduction in the intensity of the noise emitted.

One of the surprising discoveries which new means for measuring tooth profiles have revealed has been the difficulty of obtaining the desired tooth profile, particularly on large gears and this problem has not yet been satisfactorily solved. An example may be quoted where a batch of single helical gears about

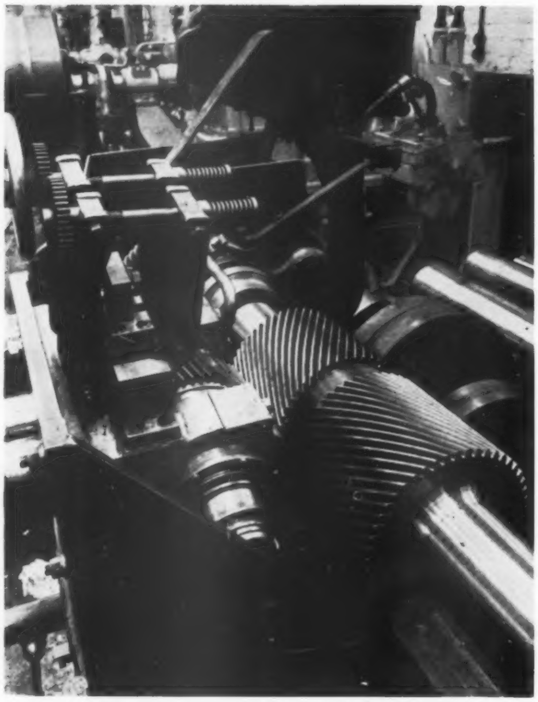


Fig. 22. Turbine pinion being shaved using tangential load with the brake applied to the cutter.

12″ diameter, 1″ face-width and 0.6″ pitch was needed to test the relative effect on performance of varying types of finish. The maximum deviation permitted from the true involute form was of the order of 0.0003″, but this proved extraordinarily difficult to attain. The hobs used were of the highest possible manufacturing standard and extreme care was expended in mounting both tool and work, but success was not achieved until the hobbing machine used was within Grade " A " limits. This result suggested that the condition of the hobbing machine is possibly the most important factor in determining the accuracy of hobbed gears.

The profile measurement of large gears of turbine type is still a problem which requires a solution that can be incontrovertibly accepted. Various instruments have been designed and some made but have yet to be proved.

Gear shaving is one of the most substantial improvements applied to gear teeth in recent years, although it is not by any means a new process since it has been used to improve the finish of wormwheel teeth for many years. Its application to spur and helical gears of all sizes, however, is a more modern development and it has proved of very considerable value in the case of large gears (Fig. 21).

The work and cutter are meshed together at the selected crossed-axis angle, but loads between them may be applied in either of two ways. In one case, the thickness of the cutter teeth is such that when meshed with the work it makes simultaneous contact with both flanks of a tooth space, but is clear of the root. By imposing a radial load and crowding the cutter further into mesh, both flanks are shaved simultaneously and the action of shaving improves finish, removes undulations unless they are excessively large and corrects small errors in pitch and profile. For normal purposes the amount of metal removed is of the order of 0.001″ to 0.002″ on each face of a tooth, and attempts to remove larger amounts by continuing to shave a gear tend to result in destruction of the true involute profile and should be avoided.

For the second method, the cutter is thinner than the tooth space of the work and load between work and cutter is obtained by braking one or other of the pair while the unbraked member is driven. For ease of operation, it is usual to apply the resistance to motion by means of a brake on the cutter spindle (Fig. 22). This type of loading is generally referred to as tangential loading and it has been extensively used. There has been some controversy about the relative merits of the two methods of shaving, but recent extensive tests using the same cutter have shown that both types of loading produced similar tooth profiles. Tangential loading was found particularly efficacious for helix correction, since by making additional passes over a desired length of the tooth helix, the helix angle could be slightly altered to remove an area of too heavy contact or to provide allowance in wide-faced gears for pinion deflection. The same result can, however, be obtained with radial loading if the cutter be provided with serrations on one flank only.

This feature of helix correction is one of the outstanding advantages of the shaving process and is particularly useful when applied to turbine pinions.

In the work conducted on shaving an interesting point has been observed that no difference in cutting section has been found between the two sides of the cutter (Fig. 23). For instance, when radial loading is being used one flank of a tooth is being shaved by the negative rake edge and the other by the positive rake edge, but all observations have failed to distin-

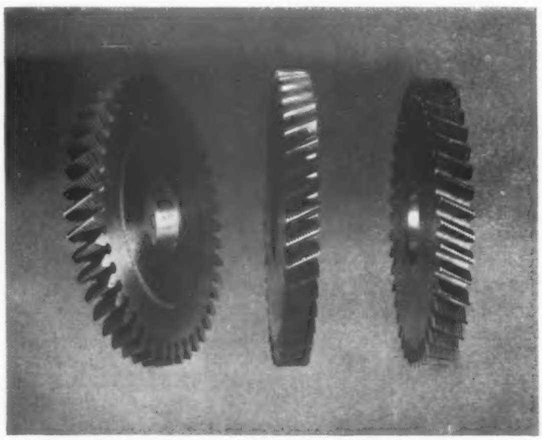


Fig. 23. Typical shaving cutters.

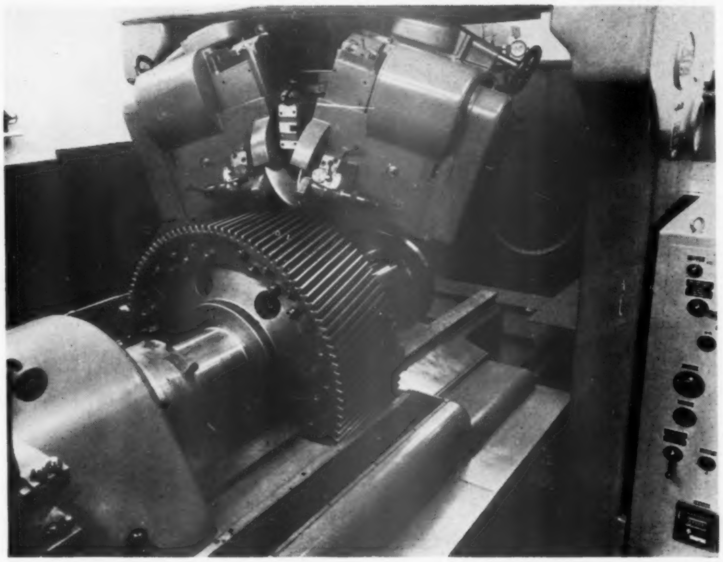


Fig. 24. Profile grinding case-hardened turbine gear in Maag P90 grinding machine.

guish any difference between the shaved finish of the two flanks. A copious pressure-fed supply of cutting fluid is necessary to remove swarf, otherwise scratches on the finished surfaces result and tend to spoil appearances although they are otherwise unimportant.

Feed is usually applied either in the direction of the work axis or in a direction which is neither parallel to the axis of the work nor to that of the cutter, and the latter is generally to be preferred, since it gives a better distribution of wear over the face of the cutter. The rate of feed usually varies between about 0.01″ and 0.02″ per revolution of the work and for the highest quality gears the smaller rate is desirable.

Profile Grinding of Gear Teeth

A further finishing process which has lost adherents in some cases within the past few years but, on the other hand, has also extended its usefulness, is the profile grinding of gear teeth. Comparatively few automotive gearbox gears are now profile ground, whereas not many years ago profile grinding was regarded as the best method of finishing such gears. Economic considerations have undoubtedly influenced this trend, but in fairness it should be borne in mind that the improvements resulting from careful control of all stages of manufacture have made the modern shaved gear at least as good as the earlier profile ground one. The shift has been away from the small ground gear to the larger sizes and the most significant modern innovation in this connection has been the application of grinding to case-hardened turbine gears. The provision of machines capable of furnishing large gears with ground profiles (Fig. 24) has had a profound effect on the design of such gears, and has opened a wide vista for future development. These large machines are capable of producing gears of as high a degree of accuracy as their small forerunners, and they also have the advantage of being able to produce tooth profiles with any desired modification from the true involute.

As with shaving, it is desirable to hob or otherwise cut gears destined to be profile ground with protuberance cutters, to prevent the formation of a step at the root of the finished tooth. Relief can be applied to tip or root or to the tooth ends as required. Both spur and helical gears can be finished by grinding and the accuracy of the product may be chosen to suit the intended purpose of the gears.

The process of grinding is based on the generating principle, in which the saucer-shaped grinding wheels form the flanks of a rack and the cylindrical pitch block concentric with the work axis, rolling on steel bands, provides the generating cylinder. The grinding wheels may be arranged either with their axes horizontal, in which case they operate at zero pressure angle, or inclined at any desired pressure angle between zero and 20°. For the former arrangement, the pitch block diameter plus the thickness of a steel tape must be equal to the base circle diameter of the work and to obtain a truly involute tooth flank the base circle must be within $\pm 0.0005''$ of the theoretical value. Since the pressure angle of engagement is purely arbitrary, the ground gears can be made to operate at any required pressure angle by designing them for a particular running pitch circle.

When using inclined grinding wheels, the diameter of the pitch block and tape thickness is made equal to the pitch circle diameter. This method is used for grinding the wheels of a gear pair or for pinions on which no profile correction is needed. All correction is applied to the pinion, and is obtained by the use of cams imparting an additional motion to the base cylinder pitch block when using the grinding wheels set for zero pressure angle. For grinding involute profiles both grinding wheels can operate together,

but for correction each flank is ground separately, since the action of the cam is to give a small additional motion at each end of the grinding stroke.

A useful secondary feature of this type of grinding machine is that it can be used as a profile measuring instrument by rolling the finished tooth profile in the correctly set up machine, in contact with a feeler actuating a measuring or recording device of sufficient sensitivity.

Accuracy

It has not been the intention in the foregoing remarks to emphasise that gears should always be of the highest standard of accuracy. The approach to perfection is always costly and this applies as much to toothed gearing as any other man-made product. For many applications extreme accuracy is unnecessary, but it is always desirable to specify the lower limit below which a product will not be acceptable. Such a policy ensures that the article will be suitable for its designed purpose and it usually means, at the same time, that it can be made for an economic cost.

The British Standards Specifications covering toothed gearing of the usual types have included the maximum permissible errors for different classes of the product based on their intended use and, provided this is clearly understood, gears conforming to the specified degree of accuracy are generally found satisfactory in service. One of the best criteria for determining the degree of accuracy required is the intended operating speed and this should always be taken into account when deciding which class to choose. Gears intended for running at high speeds should always be of "high-class" or "precision" grades, but slow-running types need rarely be better than "commercial cut" grade, unless a higher degree of accuracy is needed for some purpose unconnected with operational speed. Dividing gears and instrument gears are examples of slow-running gears where the highest attainable quality is essential.

Perhaps the "commercial" Class "C" standard is the most open to misconstruction of the term, since the majority of gear users expect the product, although intended for industrial application, to conform to the "high-class cut" group "B" specification. This is particularly true for standardised gear units and commercial vehicles requiring "high-class" spiral bevel and hypoid back axle gears.

An approximate indication of the relationship between speed and accuracy is given by a consideration of spur gears. As a type they are inherently noisy in operation, but are acceptable for certain applications where silent running is not essential. For instance, commercial cut Class "C" planed gears are permissible for pitch line speeds up to about 1,000 feet per minute; for speeds up to about 2,000 feet per minute, high-class cut gears to Class "B," produced by the gear shaping process, give reasonably satisfactory results, but if speeds up to 4,000 feet per minute are required, they should be hobbed to precision Class "A" standards. For speeds approaching 8,000 feet per minute, precision ground spur gears need not be excessively noisy, provided the necessary precautions for tip relief and mounting are observed.

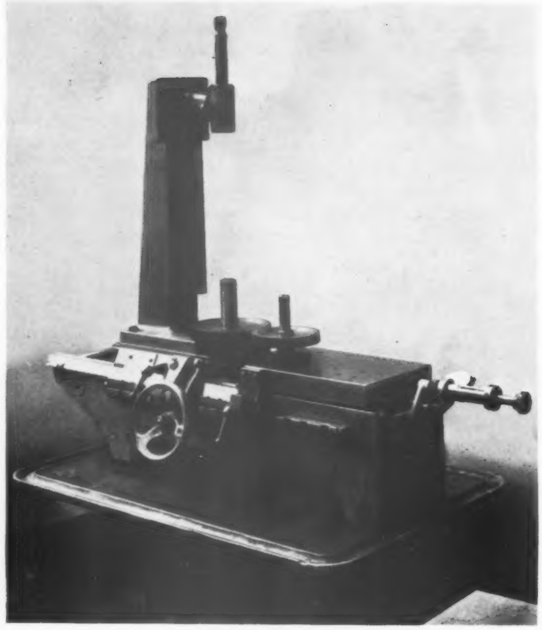


Fig. 25. Testing fixture for inspecting spur and helical gears.

Accuracy of a very high order is needed for helical gears running at pitch line speeds between 25,000 and 30,000 feet per minute if noise is to be kept within tolerable bounds.

Inspection

It need not be emphasised that a rigid system of inspection is an essential adjunct to all gear production, since only by careful control of each stage in the manufacture of a gear, from the raw material to the finished product, can the designed result be obtained. A realistic attitude to the problem must be maintained, however, to ensure a proper balance between the numbers of machine men and inspectors, and experience over a long period has shown that a satisfactory relation can be obtained by applying a few quite simple principles.

For instance, if pairs of gears are to function correctly in service they must mesh together at the designed centre distance with the desired amount of backlash, and when rolled together with a suitable marking agent they must show a satisfactory tooth contact. This is the final check test on all gears and the result is a good indication whether or not the preceding operations have been correctly carried out.

When gears are mounted into units, the manufacturer makes a final inspection of backlash and tooth contact in the gear case, but gears supplied as pairs for assembly in units or machines not produced by him have to be checked in fixtures or testing machines which reproduce the relative positions the gears will occupy in service.

A system of inspection which functions successfully in batch production is to insist that at the commence-

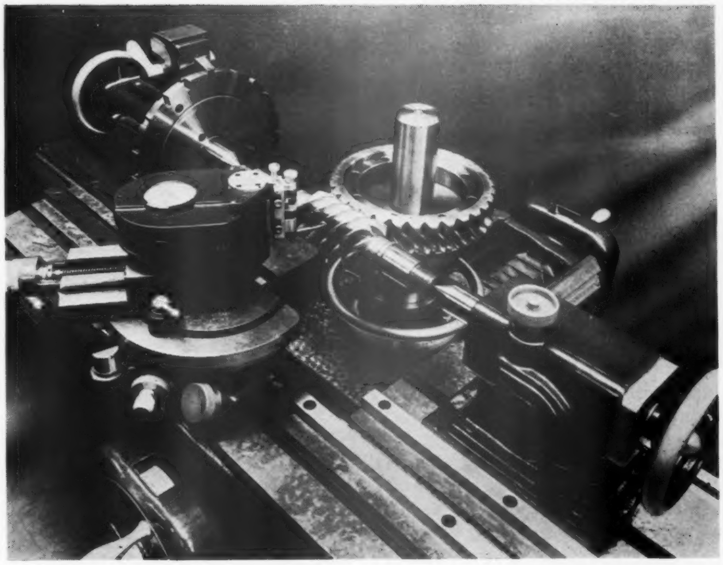


Fig. 26. Worm gears in testing machine showing measurement of worm thread profile in progress.

ment of each operation, the first piece machined is passed by an inspector before work proceeds on the bulk quantity. Thereafter about one piece in ten is inspected although it need not necessarily be the tenth piece machined. By rigorously applying this method the quality of the work maintains a consistently high standard, because the machine operator must be prepared for any sample of his work to be inspected.

Machine-cut gear teeth are always produced in a rough cut condition before the finishing operation is applied and this enables an inspector to check certain essential features such as numbers of teeth, handing, helix angle and tooth thickness. The latter is usually measured by gear tooth calipers, although a tangent micrometer or measurements taken over rollers placed in diametrically opposed tooth spaces, may be employed with equal satisfaction.

Each type of gear has its peculiarities which call for particular inspection treatment. For automobile gearbox gears, for instance, shaved and ground gears are checked for profile and helix angle. The first of a batch is thoroughly inspected and in the case of ground gears a subsequent 10% inspection is adequate to maintain quality, but with shaving, experience has shown that hundreds of gears can be produced by the same cutter with no measurable departure from the original approved shape.

Every gear is inspected individually by meshing it with a master gear and rolling the pair together in close engagement in a testing fixture (Fig. 25). This locates adjacent pitch errors by an abrupt change in meshing distance and accumulated errors by eccentricity.

It has been mentioned earlier that eccentric running is a prolific cause of operating trouble in automobile gearboxes, and a striking instance of the advantages resulting by reducing eccentricity may be cited. All completed units are given a final test run at full speed to check for noise, ease of gear change and similar points. It was found that in order to comply with an exacting acceptance standard for noise, all gears mounted on splined shafts must be positioned so that the high spots on gears and shafts tend to cancel out as nearly as possible. This is effected by marking the high positions on components during final inspection. The work involved has been fully justified by a spectacular reduction in the number of boxes rejected in the final running test.

Worm wheels are all meshed with a master worm in a specially designed testing machine (Fig. 26) to check for the position and extent of the contact bearing. The worm threads are coated with marking blue which is transferred to wheel teeth by rotating the gears together by hand. Backlash is measured by locking the worm and rotating the wheel within

Fig. 27. Spiral bevel gears being run in testing machine to check contact bearing and noise.

the amount permitted by the backlash, which is measured by a clock indicator positioned normal to a wheel tooth. The effect of wheel deflection is simulated by moving the wheel axially relative to the worm; at the full extent of deflection the blue contact marking should not quite reach the high angle or entering side of the wheel tooth flanks.

Production worms are all compared with a master worm for profile, lead angle and thread thickness in a special testing machine after rough milling and also after final grinding. Electro-magnetic methods of crack detection are utilised on the finished worms.

Bevel gears also rely on contact marking as a means for determining the accuracy of the completed gears. Unlike worm gears, bevel gears are always produced in lapped pairs and are run together in a testing machine made for the purpose (Fig. 27). A marking paint indicates the extent and location of the contact both in the initial position for the gears and also when the fully deflected condition is simulated. Under the heaviest tooth loading, contact must not extend to the heel end of a tooth flank. By running the gears together, the volume and type of noise produced is an excellent check on pitch and profile errors and on concentricity. An adjacent pitch error of a few tenths of a thousandth of an inch can be detected by this means.

Turbine gears, in keeping with the high accuracy required of them, are usually inspected more vigorously than other types and British Standards Specification 1807, Part 1:1952, lays down the permissible errors for undulations, pitch, helix angle, profile, balance and accuracy of meshing. Many of these requirements are extremely difficult to attain and mention has already been made of the trouble involved in measuring tooth profiles. As with other types of gear, however, the final criterion is the extent and position of the contact when a pair of gears having their teeth painted with a suitable marking compound, is run together.

Acknowledgment

The Author acknowledges his indebtedness to Messrs. David Brown & Sons (Huddersfield) Ltd. for permission to use information based on their methods and practice.

FUTURE INSTITUTION ACTIVITIES

The 1954 Viscount Nuffield Paper will be presented at the Royal Institution, Albemarle Street, London, on 9th December, 1954, at 6.30 p.m. The speaker will be Major-General W. A. Lord, C.B., C.B.E., Director of Mechanical Engineering at the War Office, who will take as his subject the vital importance of the application of modern production technology and management to the work of the Corps of Royal Electrical and Mechanical Engineers.

Admission to the meeting will be by ticket only, and members and friends are advised to make early application for tickets and preprints, using the form printed in the Supplement to this Journal. Tea will be served prior to the lecture.

Third Aircraft Production Conference, organised by the Southern Section of the Institution, will be held at the University of Southampton on 14th and 15th January, 1955. The theme of the Conference is to be: "Production Problems of Integral Construction contrasted with Traditional Methods".

Social Functions. Members are reminded of the following social events arranged by Sections:

Leicester Section Dinner, 25th November.

London Section Dinner Dance, 3rd December.

Shrewsbury Section Dinner Dance, 8th December.

SPECIAL PURPOSE MACHINE TOOLS AND UNIT CONSTRUCTION

by J. C. Z. MARTIN, D.L.C., Grad.I.Prod.E.

Presented to the London Graduate Section of the Institution, 18th February, 1954.

Mr. Martin, who is Sales Manager of Machine Shop Equipment Limited, was educated at Loughborough College School and Loughborough College, where he obtained an Honours Diploma in engineering.

He spent four years in the Research Department of the Institution under Dr. Georg Schlesinger, as Technical Assistant, and in 1947 joined the Production Engineering Research Association as Research Investigator. In 1950 he was appointed Research and Development Engineer with Machine Shop Equipment Limited, subsequently being transferred to the Technical Sales Department, of which he later took charge. He took up his present appointment in July of this year.

Mr. Martin serves on the London Graduate Section Committee, and is Vice-Chairman of the Hazleton Memorial Library Committee.

Mr. Martin

A VISIT to the machine shops of an up-to-date works engaged on quantity manufacture of products containing metal components, soon reveals the present trend in machine tool design. The machine shops will contain a large number of standard machine tools such as lathes, milling machines, grinding machines, drilling and boring machines performing their well-known operations. Except for sturdier construction, more power, higher speeds, more refined control and setting arrangements and more pleasing and functional outward appearance, these machines show little basic change over several decades. Here and there, however, there are machine tools which at first sight do not fall into any one of these well-known categories and require further examination before their purpose can be determined. The number of such machines in relation to the total number of machines in the shop varies, but is very roughly in proportion to the rate of production, length of production runs and progressiveness of the technical management. These are special purpose, or perhaps a better description would be "one purpose", machine tools. Their task is not to perform a given machining operation on a variety of components, but rather to perform one or more operations on a given component and they are, therefore, basically designed around that one component. It follows that this component must be one that is required in large quantities and is likely to remain in production for a considerable time.

Special Purpose Machines: Construction, Functions and General Considerations

Machines of this type are not new. They were highly developed in the U.S.A. in the past ten or twenty years, but their large scale introduction into British and Continental industry has become marked only during and since the last War.

As mentioned before, special purpose machines perform one or more operations. These mainly concern drilling, reaming, boring and milling in

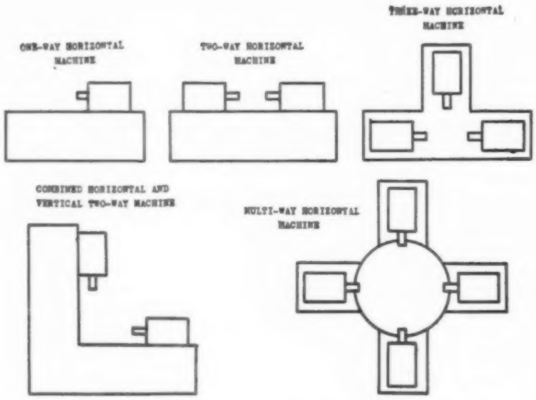


Fig. 1. Various basic arrangements of special purpose machines (work stationary).

various forms. Their superiority over universal machines is particularly marked where more than one operation is concerned, since handling times are drastically reduced, and repeated location, clamping and unclamping are avoided. There are two means of achieving this. The clamped component can remain stationary, while the machining units are being moved towards it, either simultaneously or in succession. A rapid movement rate is usually used for the cutters or tools to approach the vicinity of the component, a slower feed-movement follows during actual machining and, finally, a rapid reverse movement brings the machining units back to their starting position. There is a variety of ways of arranging the machining units and the choice will depend on the component and the machining operations to be performed on it. (Fig. 1.)

The second solution, generally adopted where a larger number of operations is involved, requires the component to be moved from station to station, in addition to the movement of the machining units.

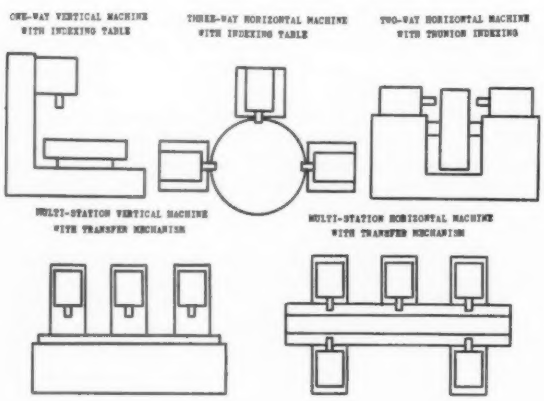


Fig. 2. Various basic arrangements of special purpose machines (work moving).

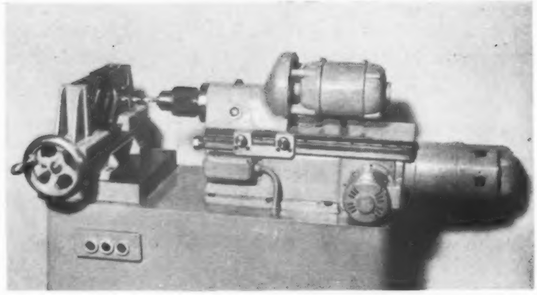


Fig. 3(*a*). Simple one-way horizontal machine with special work fixture.

Here again there is a variety of solutions, using either circular indexing or straight line indexing. (Fig. 2.) The detailed design and appearance of machines based on these principles vary greatly, as can be seen from the examples shown in Fig. 3, (a), (b), (c), (d) and (e).

Maximum benefit can only be obtained from these machines by fully automatic or at least semi-automatic operation and the control systems inevitably become relatively complicated. The power for movements and their control can be obtained in a number of combinations of mechanical, hydraulic and electrical systems. These can broadly be classified as follows: electro-mechanical, electro-hydraulic, hydraulic-mechanical, hydraulic-electrical. Each of these combinations has its own individual characteristics. For instance, hydraulic motive power enables simple stepless variation, vibration-free changes even at high feed rates, and the possibility of simultaneous control of power-operated fixtures and of forced lubrication. On the other hand hydraulic systems are sometimes affected by temperature changes which may interfere with the accuracy of time cycles. Electro-mechanical systems have other advantages. They are generally simpler, easier to manufacture and easier to maintain and are unaffected by temperature variations. The maintenance aspect is probably even more important with special purpose machines than with universal ones. The former, unlike universal machines, are seldom duplicated for any one task, because of their high production rates. A breakdown on such machines can, therefore, easily become serious in a very short time. They must, therefore, be as simple, reliable and easy to maintain as possible, consistent with their functions.

Design Considerations

The design of special purpose machines is a specialised subject and requires not only thorough knowledge of basic machine tool design, but also an intimate understanding of machining processes and, preferably, experience in machining the particular component in question.

Fixture design is frequently a very important factor and ingenious design is often required to take full advantage of the automatic cycle of the machine. An interesting illustration of this point occurred on

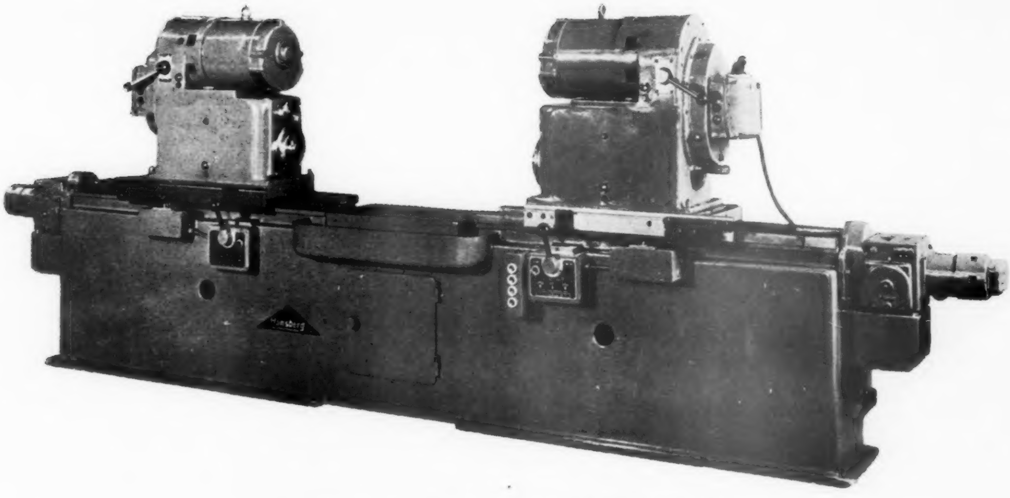


Fig. 3(*b*). Simple two-way horizontal machine.

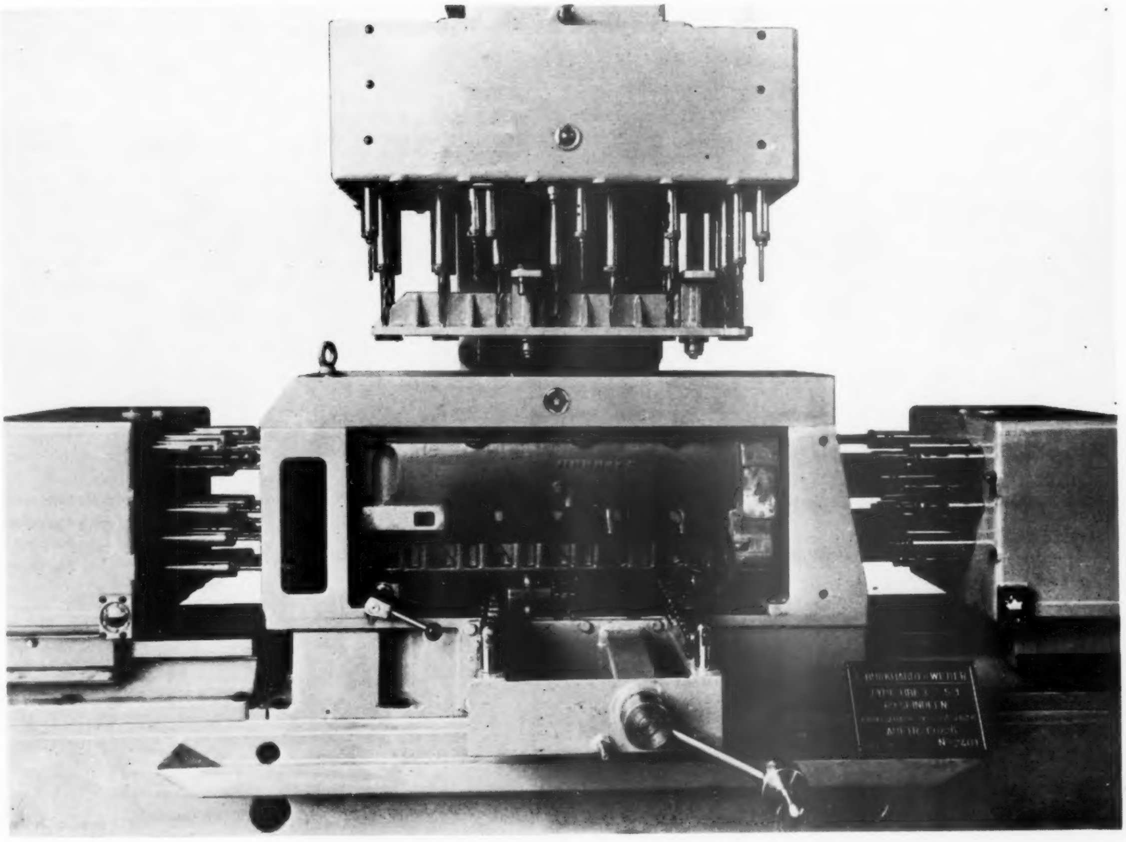


Fig. 3(*c*). Three-way combined horizontal and vertical machine.

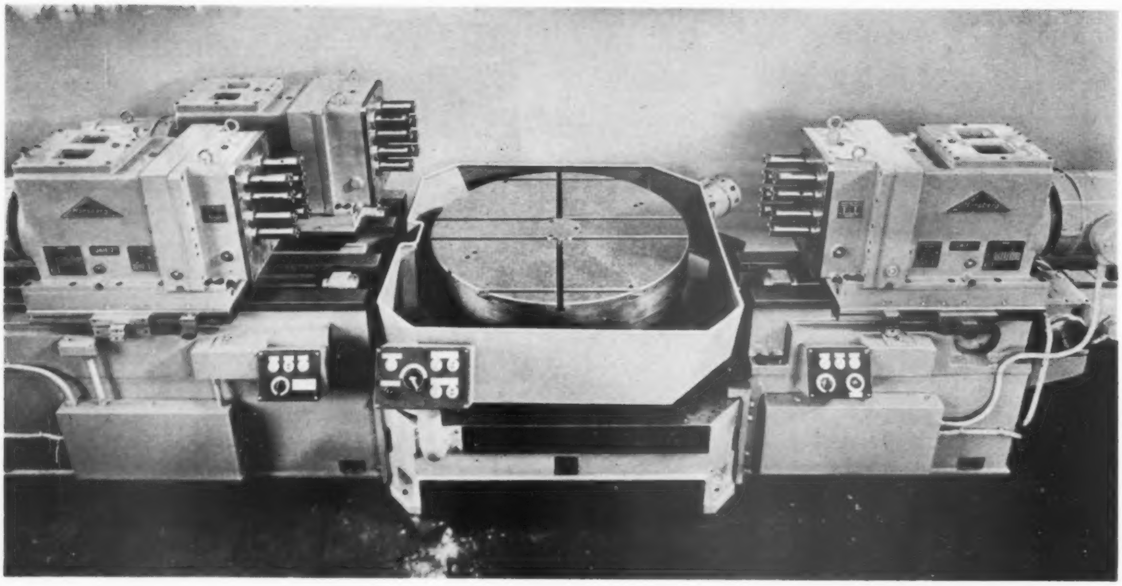


Fig. 3(*d*). Three-way horizontal machine with circular indexing table.

Fig. 3(e). Six-station vertical machine with circular indexing table.

a Canadian-built special purpose machine for bushing, burnishing, chamfering and drilling connecting rods at the rate of 600 pieces per hour. (Fig. 4.) The problem was the physical positioning of the drilled wrist pin hole in the fixture, without obstructing the operation of the various tools. It was solved by making the fixture clamping a function of the machine rather than of the operator. The connecting rods remain unclamped during the first operation and are only anchored over a locating plug in the crankshaft bearing bore. The wrist pin end is allowed to align itself for bushing and for the entry of the burnishing broach. Clamping is automatic and simultaneous with the entry of the broach into the bush. The connecting rod then remains clamped until it is automatically released at the end of the cycle.

The most important overall design considerations are simplicity and reliability in operation. The required output of the machine must be borne in mind right from the outset and where several machining operations are involved, the splitting up, combination and sequence are a primary consideration. The cycle time of the machine will be governed by the longest individual operation. It must be the designer's aim to reduce this to a minimum, and if possible combine other operations in such a way as to achieve the minimum of idle time and the minimum number of stations.

The importance of correct sequence can be seen from the following example. The operations of a large indexing table type machine included the finishing of a small bore and the finish milling of two parallel faces on a fairly small and highly accurate component. The bore, incidentally, joins the two faces. After weighing up all factors it was decided to leave the finish milling to the end. In operation it was soon found that a relatively heavy burr was thrown up during milling and this was forced into the already finished bore. The removal of the burr presented very great difficulties due to limitations imposed by the design of the component, and the theoretically ideal solution would have been the alteration of the sequence of operations. This had to be rejected at that stage due to the very considerable machine modifications this course would have involved. Although the possibility of burring was, of course, considered from the outset, a more judicious sequence of operations would have avoided the difficulty.

It is fully recognised that, technically, a special purpose machine tool provides a much more functional and efficient method of machining a component than the use of one or more universal machine tools. The latter are intentionally designed to be as versatile as possible and must, therefore, contain many features which are not required for any one machining operation. For instance, a wide range of speeds and feeds is today considered almost essential on a universal machine. The mechanical, electrical or electronic equipment required to provide this wide range, and other "universal" features, are for all practical purposes superfluous for any one operation and sometimes they are even detrimental to most efficient machining. Electrical power is being utilised for driving unnecessary gearing and

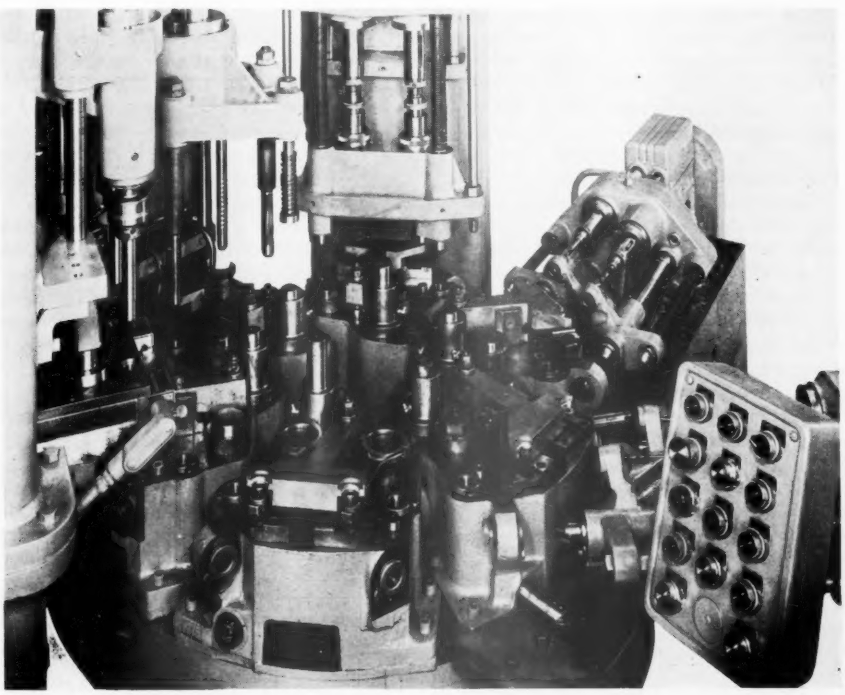


Fig. 4. Special connecting rod fixture. Clamping and unclamping are controlled automatically as a machine function.

	TRANSFER MACHINE						INDIVIDUAL MACHINES		
Production Rate per day	400	200	100	400	200	100	400	200	100
Number of Operators	1	1	1	2	2	2	4	4	4
Initial Cost of Plant (£)	37.000	37.000	37.000	37.000	37.000	37 000	26.500	26.500	26.500
Time for one Component (mins.)	1.5	1.5	1.5	1.5	1.5	1.5	2.9	2.9	2.9
Cost for one Component (pence)	22	38	70	26	42	75	47	58	79
Ratio of Fixed to Variable Costs	3.5:1	7:1	14:1	1.8:1	3.6:1	7.2:1	0.3:1	0.6:1	1.2:1

Fig. 5. Comparison of production costs using individual machines and a transfer machine.

for overcoming friction in bearings of mechanisms which do not contribute to the operation in hand. The operator's skill usually associated with universal machines is often unnecessary for special purpose machines. The number of controls, levers, handwheels, and so on, is normally relatively small on special purpose machines, as they are only required for a limited number of functions and variables. Since these machines are normally automatically or semi-automatically controlled, the operator's work consists mainly of loading and unloading components. The "skill" is virtually built into the machine at the design stage.

Economic Considerations

Since special purpose machine tools are technically superior, the only considerations which limit their wider use in industry are purely economic and these, of course, are overriding. The initial cost of special purpose machines is bound to be relatively high, as these are generally designed and produced individually. Only seldom do we find in one factory a large number of identical special purpose machines.

The two main considerations are :

(1) production rate required, and

(2) the estimated total number of components which are to be produced.

Once values are available for the required production rate and total output, both of which are determined by the estimated demand for the product, and for the initial cost of the necessary plant of the universal and special purpose type, a thorough analysis will show the relative economics of the two alternatives. The analysis must show whether the high initial cost of special purpose machines, expressed as a fixed production charge, results in a drastic reduction in the variable production costs.

The results of such an analysis are shown in an abbreviated form in Fig. 5. To illustrate the point clearly, the case is an extreme one. It compares a line transfer machine with a number of individual machines, some of which are special purpose types. In addition to showing the effect of the two types of plant on production costs, it also shows the influence of production rate and number of operators. In the case of individual machines, one operator is assumed to look after two machines. Normal operation of the transfer line requires two men, but the incorporation of an automatic mechanism which reverses the component at a certain point in the line, enables the use of one operator only.

The effect of production rate is quite clear. The difference in the cost per component is marked only at high production rates. The extra initial cost of elaborate equipment is then warranted and can be written off against a reasonable total number of components. The considerable reduction in variable production costs, which is a direct result of the high initial cost of equipment, is indicated by the ratio of fixed to variable costs for the individual cases.

Several other points connected with the production rate and total output, some of which were referred to before, should be mentioned at this stage.

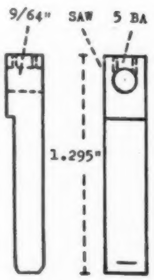
The required production rate determines the cycle time. The cycle time is also dependent on the longest operation on a multi-station or transfer machine. It is, therefore, essential that all operations be split up or combined in such a way that the times at the individual stations are as nearly equal as possible. Full use has to be made of

rapid approach and return movements. Cutting conditions have to be such that a reasonable tool life is obtained and tool and cutter changes should be regular and confined to periods between shifts. The time required for changing tools can be reduced by the provision of tool setting gauges and other similar equipment. Particular attention must be paid to loading and unloading of the component to ensure that it does not govern the cycle time. Fixtures should have time-saving clamping features and must be reliable in operation.

The estimated total output of the machine is of the utmost importance when considering the initial cost of the equipment. In cases where the component is standardised and likely to remain in production for a number of years, the advantages of special purpose equipment are quite clear. In other cases, the possibility of adapting the same machine for more than one component should be considered. A typical example of this is the machining of four or six cylinder engine blocks on the same machines. The use of unit construction in the design of special purpose machines should be mentioned here, although it will be referred to later in some detail. Unit construction gives the machine more versatility in that certain units can be used for other purposes at the end of a production run on one component. This means that only a proportion of the initial cost of the whole machine has to be written off against a particular component, whereas the cost of units, which can be re-used, can be spread over several components.

There are also other economic considerations apart from production rate, total output and initial cost of machines, which must be borne in mind

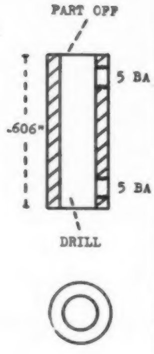
Fig. 6. Light semi-automatic special purpose machine with vertical and horizontal drilling, tapping and milling units.



UNIVERSAL MACHINES			
Machine	Operation	Hourly Output	Machine Hours
Power Saw	Saw to Width	750	66½
Sensitive Drill. M/C	Drill 9/64" Hole	825	60½
Sensitive Drill. M/C	Deburr Two Sides	790	63
Sensitive Drill. M/C	Drill 5 BA Core Hole	525	95
Tapping Machine	Tap 5 BA Hole	470	122
	Total Machine Hours :		407
UNIVERSAL MACHINE AND SPECIAL PURPOSE MACHINE			
Power Saw	Saw to Width	750	66½
Special Purpose M/C	Drill and Tap	1200	41½
	Total Machine Hours :		108
Saving on 50,000 Components : £70 10s. 0d.			

Fig. 7. Machining of brass neutral pin on universal and special purpose machines.

Fig. 8. Machining of brass terminal on universal and special purposes machines.



UNIVERSAL MACHINES			
MACHINE	OPERATION	HOURLY OUTPUT	MACHINE HOURS
AUTOMATIC LATHE	DRILL AND PART OFF	700	71½
DRILL. AND TAP. M/C	DRILL & TAP 5 BA HOLE	1635	30½
SENSITIVE DRILL. M/C	DRILL 5 BA CORE HOLE	675	74
TAPPING MACHINE	TAP 5 BA HOLE	600	83
TOTAL MACHINE HOURS : 259			
UNIVERSAL MACHINE AND SPECIAL PURPOSE MACHINE			
AUTOMATIC LATHE	DRILL AND PART OFF	700	71½
SPECIAL PURPOSE M/C.	DRILL & TAP BOTH HOLES	1200	42
TOTAL MACHINE HOURS: 113½			
SAVING ON TYPICAL ORDER OF 50,000 COMPONENTS : £35.0.0d			

when determining the relative merits of universal and special purpose machine tools. These include the most efficient use of floor space. In general, one special purpose machine requires less floor area than a number of universal machines. Labour costs when using special purpose machines are, of course, much lower, and moreover, there is the possibility of utilising semi-skilled labour instead of the highly skilled labour often required for operating universal machine tools. Quite apart from wage rates, this possibility is becoming increasingly important with the dwindling availability of skilled machine tool operators.

Maintenance costs and reliability in operation must also be considered. As mentioned before, reliability is even more critical with special purpose machines than with universal ones. Maintenance can be more time-consuming on special purpose machines, as it has to include frequent inspection to avoid serious and costly breakdowns. As with universal machines, the maintenance aspect has to be considered in the design stage to provide for easy accessibility and rapid replacement of parts which are likely to wear. Easy tracing of electrical faults should also be borne in mind by the designer.

One other point which favours multi-station special purpose machines should be mentioned. When using a series of universal machines for a number of operations on one component, locating and clamping have to be repeated on every machine. This is a possible source of inaccuracy and of scrap. On a multi-station special purpose machine the component is generally clamped in a fixture only once, so eliminating this source of possible inaccuracies. An example of this occurred only recently on the machine which was referred to in connection with the importance of correct sequence of operations. Although the initial cost of this machine is inevitably fairly high, it is visualised that it will pay for itself in a remarkably short time on this score alone, quite apart from all the other advantages of high output and labour saving.

Typical Examples

This Paper has so far attempted to deal with the nature of special purpose machines, their comparison with universal machine tools and, in a general way, with economical advantages which can under favourable conditions be derived from their use. This latter point should be stressed most and will be illustrated next by a number of specific examples.

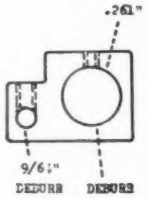
The examples are relatively simple ones and are taken from the light electrical, Diesel engine and motor-car industries.

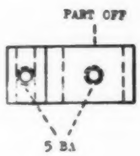
The first three examples concern a simple, light, semi-automatic special purpose machine. It is built up of standard drilling, tapping and milling units and incorporates an automatic indexing table. The indexing of the table and the movements of the machining units are automatically controlled by a system using Bowden cables. Loading and unloading of components are normally by hand, but manual unloading can be replaced by automatic ejectors. (Fig. 6.)

The first component is a neutral pin of an electric plug (Fig. 7).

Another component illustrating the considerable savings is an electrical terminal (Fig. 8)., and finally, a fuse terminal also partially machined on the same special purpose machine is shown in Fig. 9.

The next example concerns a much heavier special purpose machine consisting of three heavy horizontal machining units and a large indexing table (Fig. 10). It is designed for drilling, counter-drilling, spot-facing and reaming Diesel engine connecting rods and connecting rod large end blocks. The multi-spindle unit on the right-hand side drills four holes in the forked big end of the rod, one of the units on the left-hand side faces a 1 3/16" diameter nut seating; the table then indexes and the second unit on the left-hand side finish-reams the already drilled holes to a diameter of 9/16". The multi-spindle heads are equipped with a duplicate set of spindles, so that different types of connecting rods can be machined. The change-over only requires a second





Machine	Operation	Hourly Output	Machine Hours
UNIVERSAL MACHINES			
Power Saw	Part off to Width	1125	44½
Sensitive Drill. M/C.	Drill 9/64" Hole	450	111
Sensitive Drill. M/C.	Drill 0.261" Hole	450	111
Sensitive Drill. M/C.	Deburr 2 Holes, 2 sides	300	167
Sensitive Drill. M/C.	Drill 2-5 BA Core Holes	375	133⅓
Tapping Machine	Tap 2 - 5 BA Holes	375	133½
		Total Machine Hours :	700⅓
UNIVERSAL MACHINES AND SPECIAL PURPOSE MACHINE			
Power Saw	Part off to Width	1125	44½
Sensitive Drill. M/C.	Drill 9/64" Hole	450	111
Sensitive Drill. M/C.	Drill 0.261" Hole	450	111
Sensitive Drill. M/C.	Deburr 2 Holes, 2 sides	300	167
Special Purpose M/C.	Drill and Tap 2 Holes	1200	41½
		Total Machine Hours :	475
Saving on a Typical Order of 50,000 Components : £35 0s. 0d.			

Fig. 9. Machining of brass fuse terminal on universal and special purpose machines.

built-up fixture and a second set of cutting tools, mounted in the duplicate spindles. The whole cycle of operations is automatically controlled, so that the operator need only load and unload components and start the cycle by push-button control. The individual operations can, of course, also be performed and controlled separately.

Before the installation of this machine all the operations were performed on radial drilling machines. The savings when using the special purpose machine are again quite remarkable. For instance, they can be illustrated by taking the example of one type of forked connecting rod :

Fig. 10. Three-way horizontal machine.

Machining time on special purpose machine: 20 minutes.*

Machining time on radial drilling machines: 46.5 minutes.*

*These times allow for bonus earnings.

Machine hourly rate	10/- per hour
Monthly output:	200 components
Monthly cost on special purpose machine:	£33 6s. 8d.
Monthly cost on radial drilling machines:	£77 10s. 0d.
Monthly saving:	£44 3s. 4d.

Similar savings are achieved on four different connecting rods and greater savings still on three types of large end blocks. The overall savings over this whole range of components are in the order of 5,000 hours, or £2,500 per month.

The last example illustrates an installation of three special purpose machines which are used in sequence for drilling, tapping, reaming, facing, recessing and other similar operations on the water pump of a well-known motor car. (Fig. 11 (a), (b), (c).) The number of individual operations on the first machine is 34, on the second machine, 11 and six on the third machine. All three machines have a central horizontal indexing table around which are grouped horizontal, vertical and inclined machining units. The components are loaded into fixtures which are permanently mounted on the indexing table. After clamping, the component is indexed from station to station for various operations. The first machine has five working stations, the second machine has four and the third machine has three working stations. Several multi-spindle heads are used where there are suitably grouped operations. The operations range from drilling small holes of $\frac{1}{4}''$ diameter to core drilling holes over 1.8" diameter and facing a three-inch diameter face. The second machine has a rather unusual feature in that an inclined drilling unit is mounted on the indexing table. At the second station this unit and a second similar, but externally mounted, drilling unit, produce two 9/32" diameter holes inclined at 30° to the main locating face of the pump body. The third machine is arranged for two loadings. The component, after having been through one cycle, is repositioned in another fixture and reclamped, and passes through the machine again for another series of operations. A $\frac{1}{16}''$ machining allowance is left on all machined faces before the components come to these machines and the centre bores are cored.

This installation results in a very considerable time saving. The operations were previously carried out on capstan lathes and radial drilling machines and the total time per piece was 26.9 minutes. The total time per component on the three special purpose machines is planned to be 9.26 minutes; reduction is therefore 17.4 minutes. The financial savings, taking into account the large and continuous output and the reduction in number of operators, are quite obviously very substantial.

Unit Construction

Finally, a few words about unit construction as used in special purpose machine tool design.

The idea of standardised machine tool units or elements is relatively new, but it has certainly received a great deal of attention during and since the recent War. It is interesting to note that the idea is not only being developed and exploited by machine tool manufacturers, but also by large users of machine tools. At least two large motor-car manufacturers, one in this country and one in France, have designed ranges of machine units, and the latter is actually marketing them.

Unit construction should contribute to the wider introduction of special purpose machine tools for the following reasons:-

A special purpose machine, built from standard units, should be simple. Its cost should be relatively low, because the units are produced in batches.

The design of the special pupose machine is easier, as much of the data is already available in the form of specifications of standard units. Design time is therefore reduced.

The total time from the order stage to the completion of the machine can further be reduced, if some or all of the required units are in stock.

Modifications of products or complete changes of products do not necessarily entail the scrapping of the entire special purpose machine. The individual units, which form the machine, can be re-used by building them into machines to suit new requirements. Unit construction can simplify maintenance. Defective units can be removed for repair and overhaul, while replacement units are fitted in their place. The down time due to breakdowns is therefore reduced.

A complete system of units consists of a whole range covering most elements of a machine tool. There are the actual machining units of various types, table units, bases, and various auxiliary units providing feed and rapid motions, work traverse, indexing and so on. The units are generally available in a range of sizes and machining capacities, and their design is often based on experience in the production of universal machine tools. They therefore incorporate up-to-date ideas in the design of drives, bearings and control systems. The units are generally quite self-contained.

A typical complete range of units which form the manufacturing programme of one Continental machine tool maker has two main divisions, each of which contains seven sub-divisions. These subdivisions represent various types of units or elements and are available in a range of sizes (Fig. 12).

Drilling units are the most widely used machining units and some machine tool manufacturers produce several types. The feed motion is generally provided through separate table units on which the drilling units are mounted. This is very advantageous in

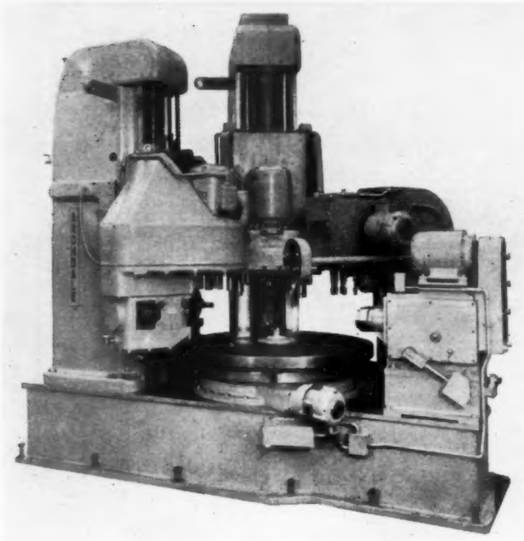


Fig. 11 (*a*). Five-station combined horizontal and vertical special purpose machine.

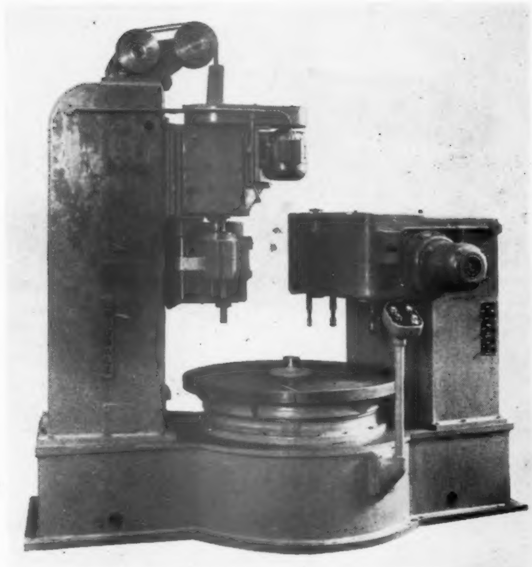


Fig. 11(*c*). Three-station vertical special purpose machine.

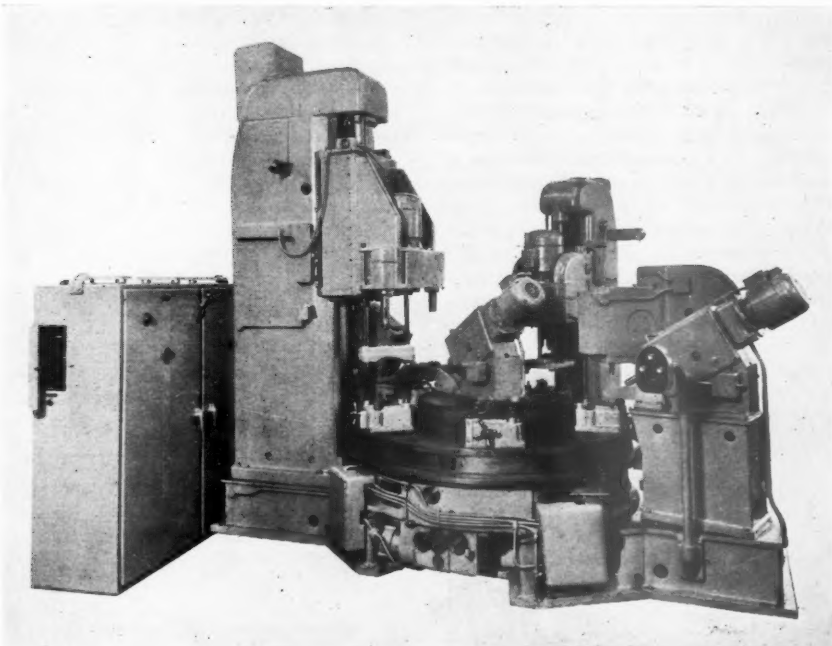


Fig. 11(*b*). Four-station combined vertical and inclined special purpose machine.

MACHINING	TYPE OF MACHINING OPERATION	B	DRILLING UNITS	DRILL. CAP IN STEEL *	6	10	16	25	40	63	100	
		G	TAPPING UNITS	TAP. CAP. IN STEEL *	6	10	16	25	40			
		D	TURNING UNITS	POWER KW	1	2	4	8				
		P	FACING UNITS	POWER KW	1	2	4	8				
		F	MILLING UNITS	POWER KW	1	2	4	8	16			
		S	GRINDING UNITS	MAX. WHEEL DIA *	25	50	100	200	350	500		
		A	DRIVE UNITS	POWER KW	0.5	1	2	4	8			
MOVEMENT	AUXILIARY EQUIPMENT	EV	FEED & RAPID TRAV. UNITS	TORQUE **	0.4	1	4	16	40	100		
		TE	TABLE UNITS	TABLE WIDTH *	160	200	250	315	400	500	630	800
		GM	BASE UNITS	TABLE WIDTH *	250	315	400	500	630	800		
		RE	CONVEYOR UNITS	TABLE WIDTH *	250	315	400	500	630	800		
		RU	INDEXING UNITS	DIAMETER *	315	400	500	630	800	1000		
		FE	TRANSFER UNITS	TABLE WIDTH *	250	315	400	500	630	800		
		ES	ELECT.CONTROL UNITS	CAPACITY KW	2	5	1.6	40				

* in mm. ** in mkg.

Fig. 12. Range of machines tool units.

that the drilling unit remains quite simple and that the cutting tool remains at a constant minimum distance from the main spindle bearing, irrespective of the approach distance and the depth of the drilled hole. In some cases, however, particularly for simple roughing operations, involving only short depths, the spindle of the drilling units themselves feeds forward. The drive is generally from a built-in electric motor. The versatility of a drilling unit can be extended by the addition of various auxiliary equipment. It is quite common, for instance, to fit multi-spindle heads on these units, as in Fig. 13; alternatively, a facing attachment can be used (Fig. 14). This can be operated mechanically or hydraulically and brings a wide range of machining operations within the scope of a basically simple unit. Other requirements can be satisfied by the addition of change gears to provide various spindle speeds, a steplessly variable spindle drive, a steplessly variable feed drive, a deep hole drilling device providing swarf clearing action to pre-set requirements and a threading attachment to give automatic spindle reversal prior to withdrawal of the tap.

One of the most important auxiliary units is the table unit which often incorporates a feeding device, feed controls and trip dogs when working with an automatic cycle (Fig. 15). This particular unit is again available in a range of sizes to suit the standard sizes of machine units.

The standardisation of the electrical control equipment and its construction in easily connected self-contained units is most important for the same reasons that apply to the mechanical units. The maintenance aspect here is, perhaps, even more critical.

It is, of course, not always possible to construct an entire special purpose machine tool from standard units, particularly when the machine is a fairly complicated multi-station type. It is then often

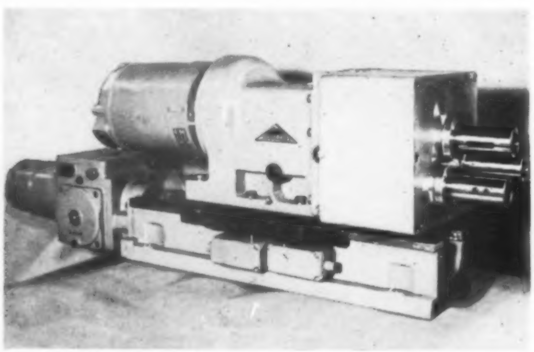


Fig. 13. Multi-spindle head mounted on drilling unit.

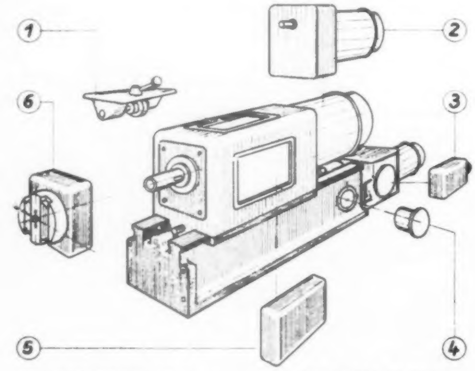


Fig. 14. Drilling unit with additional equipment.

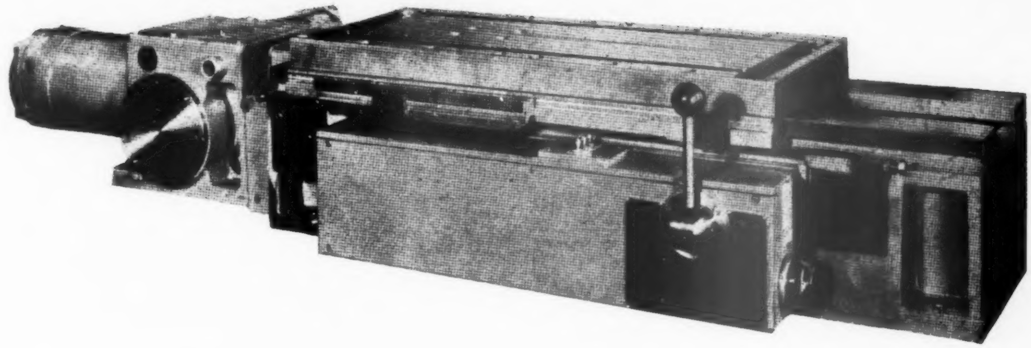


Fig. 15. Unit construction worktable with feed and rapid traverse control.

necessary to design special units, bases and other elements which do not come within the standard range of units. Nevertheless, this does not invalidate the overall advantages of the unit construction principle.

Conclusion

It is hoped that this short survey of special purpose machines has indicated what they are, how they differ from universal machine tools and what they can do, under suitable conditions, to reduce machining times and costs. It must be quite clearly understood that very considerable savings are possible, but they depend on the nature of the machining operations, production rate and total quantities, and, of course, on suitable machine design.

The principle of unit construction in machine tools, although also applicable to universal machines, is particularly useful in the case of special purpose machines, as it reduces their initial cost and time for design and construction, and increases their versatility.

It should be mentioned that the examples used illustrate only a very small fraction of the various types of special purpose machine tools in use in industry today.

Acknowledgments

Free use has been made of information published in the technical press of this country and the Continent.

Full acknowledgment for their kind assistance in the form of information and illustrations is also made to the following companies: James Archdale & Co., Ltd., Messrs. Burkhardt & Weber, Davey Paxman & Co., Ltd., Elgar Machine Tool Co., Ltd., and Oerlikon Italiana, Sidney G. Jones and Kingsbury Machine Tool Corporation, Modern Tool Works, Ltd., of Toronto, Nettle Accessories, Ltd., Vauxhall Motors, Ltd., and particularly to Messrs. Honsberg, Hahn & Kolb and Machine Shop Equipment, Ltd.

BRITISH STANDARDS

The following Standards have recently been issued and may be obtained, post free, at the prices stated, from the British Standards Institution, British Standards Institution, British Standards House, 2, Park Street, London, W.1.:

B.S. 1054: 1954—Engineers' comparators for external measurement. (2/6)

B.S. 411: 1954—Circular saws for woodworking and their attachment. (3/-)

RESEARCH PUBLICATIONS

A number of copies of the following Research publications are still available to members, at the prices stated:

Report on Surface Finish, by Dr. G. Schlesinger	15/6
Machine Tool Research and Management	10/6
Practical Drilling Tests	21/-

These publications may be obtained from the Production Engineering Research Association, " Staveley Lodge ", Melton Mowbray, Leics.

THE SHELL MOULDING PROCESS

by D. N. BUTTREY, MSc., A.R.I.C., A.P.I.

Presented to the Reading Section of the Institution, 4th March, 1954.

Mr. Buttrey

Mr. Buttrey, of the Plastics Division of Imperial Chemical Industries, Limited, is the author of several books on plastics technology and has given numerous Papers on shell moulding, including one to the 50th Annual Conference of the Institute of British Foundrymen, in 1953, and another to l'Assemblé Generale Charleroi, 1953 (l'Association Technique de Fonderie de Belgique).

He was educated at William Hulme's Grammar School, Manchester, and the Royal Technical College, Salford, and has worked in the plastics industry since 1941, mainly on research and development. He has had specialised experience of the use of resins for foundry practice since 1946.

A PATENT application (No. 48679) was filed in the German patent office on 1st February, 1944, on the process of making thin moulds and cores with approximately uniform wall thickness, from dry-sand-resin mixtures, also including the use of fillers such as metal powder, metal oxides and graphite.[1] This patent application was kept secret by the German Government, although by June, 1944, the process was in production at several foundries[1, 2] and at the firm of Haller Werke A.G. in Hamburg-Altona the production of cores for 8-cm. hand-grenades by the process had reached a figure of 6,000 components per day.

The first technical details of the shell-moulding process, also referred to as the " C " process, based on the interrogation by W. W. McCullogh (of the Technical Industrial Intelligence Division, U.S. Dept. of Commerce) of J. Croning in Hamburg, were published as a Report No. 1168 of the Office of Technical Services, U.S. Dept. of Commerce on 30th May, 1947.

During the past six years, development of the shell-moulding process has proceeded more rapidly in the United States than in Great Britain and it is now being used in a number of foundries, including that of the Ford Motor Company (U.S.A.) where, it is stated,[3] an estimated 150 tons per day of metal is poured into shell moulds to make at least 40,000 exhaust valves daily, and also camshafts, crankshafts and rocker arms: it is estimated that in the new Ford " 6," shell-moulded parts comprise approximately 15% of the total engine weight, and to date this company has invested perhaps $8 million in the process. In Great Britain, the process is now in operation in several foundries, although as yet on a comparatively limited scale. Nevertheless, in one foundry, 14,000 castings, including compressor crank-cases and cylinders, and internal combustion engine cylinders and heads have been shell-moulded during 1952.[4] Interest in the process is considerable and development work is now widespread. In Denmark,[5] from December, 1950, to July, 1951, some 6,000 small engine cylinders were produced by the process and, in spite of the experimental nature of the production, the total percentage of waste was below the previous figures relating to oil-sand moulded cylinders. At the present time a considerable volume of technical literature on shell moulding is appearing, giving details of wider application of the process.

Estimates on the future of shell moulding in the

United States have been very ambitious; for example it has been forecast[3] that resin consumption by the process will be nearly 80 million pounds in 1957 (equivalent to over 400,000 tons of sand shells), and that shell moulding will replace half of all sand casting within ten years; although such phenomenal expansion is certainly not anticipated in Great Britain, nevertheless it would appear only a matter of time before shell-moulding becomes an established part of foundry practice in this country. It is of note that interest in shell-moulding for cores has increased greatly in the past few months.

Approximately fifteen companies in the United States are now offering commercial machines[6] for making shell moulds and their designs are of two general types, i.e., single-station machines, which provide a single pattern with its own oven, and multi-station machines carrying from two to a dozen patterns through a common oven. The multi-station machines are designed for mass-production work, one machine producing 1,000 shell moulds per hour on a 12-station turntable. British Patents have been granted relating to apparatus for making casting cores and the production of metal patterns, and apparatus for cooling shell moulds during casting.[7] In Great Britain four shell-making machines are now in production, and several others are being developed. A number of foundries are designing their own machinery for shell moulding.

Characteristics of the Process

To assess the value of the shell-moulding process for foundry use, it is necessary to compare it with the other processes at present available for metal casting.

(i) *Surface Finish*

The shell-moulding process gives high surface finish to castings and considerably reduces finishing operations. This is because it is possible to use sand of finer mesh size than can be employed in normal sand-moulding techniques at the same time achieving equal permeability. The use of a relatively high binder concentration in the sand holds the fine sand together firmly to give a smooth, hard, casting surface to the mould.

(ii) *Casting Size and Dimensions possible*

The shell-moulding process is particularly suited to casting thin sections where high definition is required, for example, air-cooled petrol-engine cylinders. Cross sections of $\frac{1}{16}''$ of appreciable length are readily moulded by the process. The permeability of mould walls is high; it is, therefore, possible to eliminate gassing difficulties in certain types of castings. For ferrous metals, it is possible to obtain as good results as with die-casting methods for non-ferrous metals. Even for non-ferrous metals,[1] shell-moulding is competitive with plaster or die-casting for mass producing smooth castings which require little or no finishing.

At the present time, there are definite limits to the production of larger castings by the process. Unless shell wall-thicknesses are used such that the method becomes uneconomical, only a limited weight of molten metal can be supported, although backing of the shell during casting, and cooling of such backing,[8] may do much to increase the limits of size of casting possible, and whereas until recently, castings of 20 to 30 lb. in weight were considered an upper limit, castings several hundredweight in size have now been made.

It must also be realised that pattern design has to be such that shells can be lifted from the pattern after forming and therefore, although inserts may be placed in the shell moulds that allow undercuts in the final casting, nevertheless greater intricacy of castings is possible with the lost-wax process. At the same time, techniques involving the use of shell moulds comprising three or more separate sand shell components are being developed, thereby allowing for greater intricacy of casting.

(iii) *Dimensional Accuracy*

Castings made by shell-moulding are characterised by sharpness of definition and low tolerances, compared with those made by conventional sand-moulding techniques. Tolerances of 0.003" per in. are possible and even closer tolerances are claimed. Recent tests on dimensional accuracy using grey iron cylindrical specimens 6" in length have shown average tolerances of the order of 3-5 thousandths of an inch along the length of the specimen, allowing for the normal heat shrinkage of the metal, i.e. along the plane of the shell. On the question of tolerances, the problem of matching up of shells is important and it is obvious that if bowing or distortion of the shell occurs during forming, tolerances will be considerably greater across certain sections of castings. The practice of providing bolt-holes through the shells at a number of points so that the two shell halves may be firmly bolted together will correct minor distortion of shells. If major distortion occurs, this can only be corrected by modification to the basic design of the pattern. Tolerances across the shell are more difficult to control and depend on accuracy of matching of the shells, also on weight of casting. An ordnance cover casting[6] in aluminium-silicon alloy (5% Si) has been held to $\pm 0.015''$ on overall length and width and to $\pm 0.005''$ in the width and depth of the gasket groove.

(iv) *Economics of Shell-moulding*

The economics of the shell-moulding process are difficult to assess, and can be considered only in relation to the specific requirements of individual foundries. The basic cost of the sand/resin mixture suitable for shell-moulding is relatively high. Pattern costs are high. Offsetting these is the fact that for both mould and core work, the quantity of sand used is only a fraction of that used by normal sand-moulding techniques. Handling costs are reduced, also fettling and finishing costs. For core work, the rapid-hardening cycle of shell cores means consider-

able savings in fuel for a given number of components.

Indirect savings will also result from reduction of scrap due to gassing, also tearing on thin sections of castings. For certain applications, quality of castings will justify the higher cost of the mould. Of particular note is the fact that for new production, or where expansion in the foundry is envisaged, both the capital equipment and the foundry space required to introduce shell-moulding for a given volume of work can be considerably less than where conventional sand-moulding techniques are used.

(v) *Storage of Shell Moulds*

Shell moulds can be stored for long periods without apparent deterioration, and the weakening due to moisture absorption or " striking back " observed with many oil-sand resin-bound sand cores does not occur in sand shells. Shells that have been stored under normal, dry conditions have shown no visible surface friability after twelve months. The fact that shell moulds can be stored and be immediately available for use at any time is of some importance from the production viewpoint and enables runs of components to be made at short notice.

Basic Operation of the Shell-Moulding Process

The shell-moulding process is essentially a method of manufacture of sand moulds and cores for foundry casting in the form of relatively thin shells of approximately uniform wall thickness. The process of making such shells is one by which a dry, powdered sand-resin mixture is brought into contact with a heated metal pattern under such conditions that the required thickness of shell is rapidly formed on the pattern, after which the shell is hardened, while still on the pattern, by the application of heat. The hardened shell is then lifted from the pattern. For use as a mould for casting, two such shells are clamped together, cores being inserted where necessary. During casting, the shell moulds may be merely supported by mechanical means to allow the metal to flow correctly through the runners, or, alternatively for certain applications, may be backed with loose granular material.[8] Other supporting techniques are being developed.

PRACTICAL OPERATION OF THE SHELL-MOULDING PROCESS

Raw Materials

The sand required for making sand shells is a fine, dry, silica sand, free from clay and organic impurities and, if necessary, sieved to eliminate sea shells and coarse particles. Sand of 100-150 mesh B.S. sieves is desirable; coarser particles than approximately 100 mesh give strength to the shell but mar surface finish and, above 150 mesh, the strength of the shell is decreased without corresponding improvement in surface finish. Experience in the United States confirms the particle-size grading necessary to achieve good results. Independent workers[1, 10] have shown

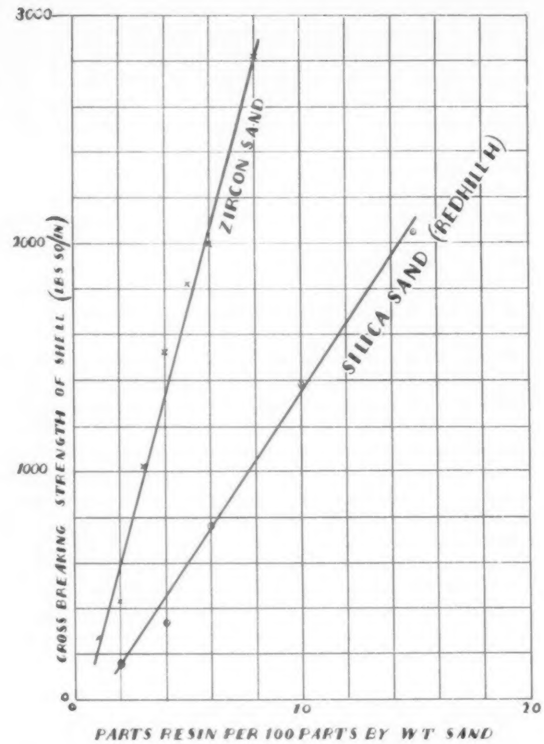


Fig. 1. Comparison of silica sand and zircon sand—effect of variations in resin binder P.F. 422/1 on shell strength.

that sand of 151 A.F.S. fineness requires 9% resin to bond it and gives a very good surface, whereas one of 103 A.F.S. fineness gives a good surface, but only required 8% resin to bond. A round uniformly grained sand of 100 to 150 A.F.S. fineness is sometimes preferred;[1, 11] clay contents should be low, the limits given being in one case below 1%[1, 12] and in another below 3%[1, 13]

In shell-moulding, the value of ingredients in the mix other than sand and resin binder is still being determined. Plumbago and terra-flake have been proposed[14] to improve the shell surface and increase resistance to metal penetration; inhibitors may be added for light alloy casting. The incorporation of a certain percentage of coarse-grain sand in the mix will improve shell strength without appreciably affecting surface finish; zircon sand is also of advantage to decrease the tendency towards metal penetration. It has been stated[6] that on medium carbon steel castings zircon flour additions of 7.5-10% substantially improves surface quality. Zircon sand gives a shell of greatly increased density and allows considerably less resin binder to be used to obtain high shell strengths compared with silicon sands (Figs. 1 and 2). This may be of significance for steel casting to reduce the danger of carbon pick-up. Iron oxide additions have shown no significant improvement in surface finish of castings, although

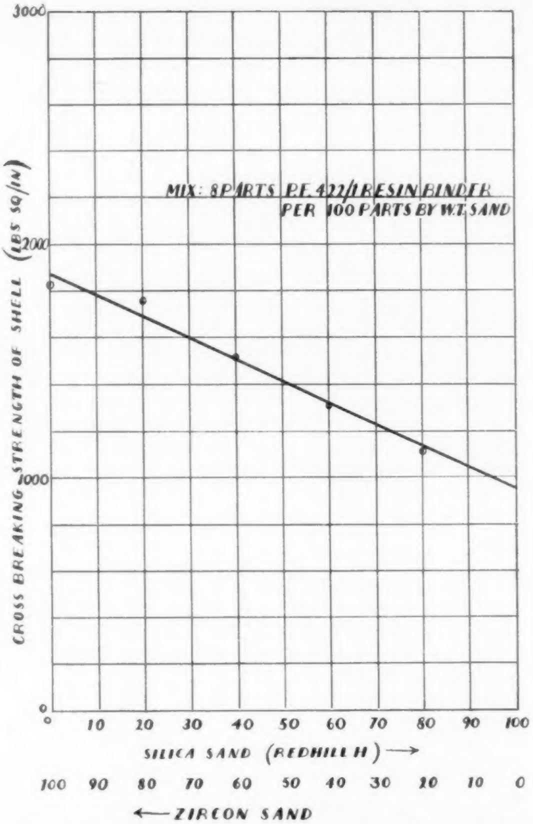


Fig. 2. Strength of shells made from silica/zircon sand mixtures.

up to 5% appears to be of benefit in reducing "peel-off" of the shell from the pattern after investment.[6]

The type of resin binder most satisfactory to date has been a so-called 2-stage phenolic resin mixed with accelerator, in a finely-powdered condition. This type of resin derives its name from the fact that unlike many other resins used in foundry, it will only harden when it is heated with the accelerator. The particular technical difficulty referred to as "peel-off," i.e. dropping off of the shell during investment when an inverting box is used, is closely bound up with the type of resin employed. It has been found possible to produce a resin completely free from "peel-back" difficulties over a wide range of investment temperatures. Extended trials on such a resin, P.F. 422/1, using different pattern temperatures, has shown an absence of "peel-back" on every occasion.

Some work has also been done with powdered urea-resin (U.F.) binders,[15] but, to date, phenolic resins of the two-stage type have found most application in shell moulding. To prevent separation of the powdered resin from the sand during moulding operations and to reduce dust, it is now established practice to add a small percentage of either wetting agent or a liquid phenolic resin to the mix. Small percentages of paraffin, or alternatively mineral oil, have been found beneficial in reducing dust.

Mixing

For ferrous casting, the following proportions of sand and resin binder are in general satisfactory for shell forming:—

Dry silica sand, 100 parts by weight.
Powdered phenolic resin binder, 6 to 8 parts by weight.

The actual amounts must depend on the particular sand and resin binder used, and for non-ferrous casting it is possible in certain designs to reduce the resin content appreciably. It is found that, with a given sand and resin binder, the surface finish of the shell varies little with different resin contents within the range under consideration but, on the other hand, both the compression and tensile strengths of the shell and the surface friability property depend on the binder content of the mix.[16, 17]

Within the range 5-10% resin binder addition, it has been found that an approximate straight line relationship exists between binder content and cross-breaking strength of shell specimens (Fig. 1).

It is essential, during mixing, to ensure that the resin binder is dispersed uniformly throughout the sand; local concentrations of resin in the shell will give resin "spots," which can be responsible for gassing during casting. For mixing, a rotating tumbling-type mixer is preferable to conventional foundry sand mixers, which are liable to deposit unmixed material on the bottom and sides of the mixer and round the blades. The powdered resin, which is normally supplied in moisture-proof containers, should not be allowed to stand in contact with the air for undue periods before mixing. Once mixed, the product will store for reasonable periods in a normal dry atmosphere. It is wise not to allow the temperature during mixing to rise above 50°C. and hot sand from the dryer must not be used, as is sometimes the practice in normal core-sand mixing.

Other ingredients in the mix, such as wetting agent or a liquid resin, may be added; these should be first mixed with the sand to wet the surface uniformly, and the powdered resin binder then added.

Lubrication of the Pattern

Without pattern lubricant, the hardened shell will adhere firmly to the pattern and be irremovable without fracture.

For lubrication, separating agents based on silicone resins have been found most generally acceptable. Examples are silicone oil F.115, which is a clear liquid suitable for brushing and spraying, silicone grease D.C.7, which is a grease suitable for wiping over the pattern surface, or silicone emulsions. Comparative tests the Author has carried out suggest that the oils and greases give a more continuous film on the pattern with improved covering power, whereas the emulsions tend to deposit the silicone resin in discrete particles. If the pattern is given two or three pre-treatments with the silicone separating agent, each application being baked on the pattern at 200 to 300°C., then a semi-permanent lubricating surface is built up, from which a considerable number

of shells can be lifted with only occasional lubrication between operations. A more economic separating fluid can be prepared from silicone oils by dilution with solvent.

Polytetrafluorethylene (P.T.F.E.) gives a good permanent lubricating surface to the pattern. An alternative grease for pattern lubrication is "Gargoyle H.T." grease, which is both very effective and economical in use. Montan and other waxes have also been proposed for pattern lubrication.[9] To effect separation of the shell after hardening, adequate ejector pins or plates on the pattern are essential.

Pattern and Oven Temperatures

Pattern temperatures ranging from 150 to 300°C. are normally recommended but actual pattern temperature must depend on design of the pattern and type of resin binder used. High pattern-temperatures give faster build-up of the shell and decrease hardening time, although the latter can be controlled by oven temperature. On patterns where design is such that both heavy and light sections are present, the use of high pattern-temperature will give very rapid build-up and hardening on the heavy parts at the expense of the light sections during a given investment and oven time, so that there may be a tendency to over-cure the shell on the heavy parts and insufficiently cure the shell on the lighter sections. Alternatively, a low pattern-temperature, combined with a high oven-temperature, can cause burning of thin sections protruding from the shell (Fig. 3).

In general, a pattern temperature of 200 to 250°C. has been found most useful, with an oven temperature of approximately 300°C. For rapid production of shells, a comparatively low pattern-temperature (200°C.) has been used in combination with a high oven-temperature (400°C.). This system is useful in maintaining pattern temperature during production.

Investment Time

When an inverting box is used for shell forming, the investment or build-up time of the shell depends on the thickness of shell required, the temperature of the pattern, and the thickness of the pattern. In general a minimum thickness of pattern desirable is ½", although it must be realised that many sections on the pattern will be below this thickness.

The temperature of the pattern has considerable effect on the rate of build-up of shell, this being illustrated by the following published data[12]:—

Pattern: Cast Iron.

Thickness of shell build-up: $\frac{3}{16}$"

Temperature, deg. C.	149	177	204	232
Time required (seconds)	21	12	10	7

At pattern temperatures of 200 to 250°C., the time to build up a production shell usually lies between 10 and 25 secs., depending on the thickness required.

Hardening Time

Where oven heating is used to harden the shell, hardening time depends on oven temperature, pattern temperature, and thickness of shell. At a pattern temperature of 200 to 250°C., and an oven temperature of 300°C., hardening time usually lies between 1 and 4 min. Higher oven-temperatures, as indicated earlier, will reduce shell hardening time. A total cycle time of as low as 1 to 1½ min. has been claimed.[3]

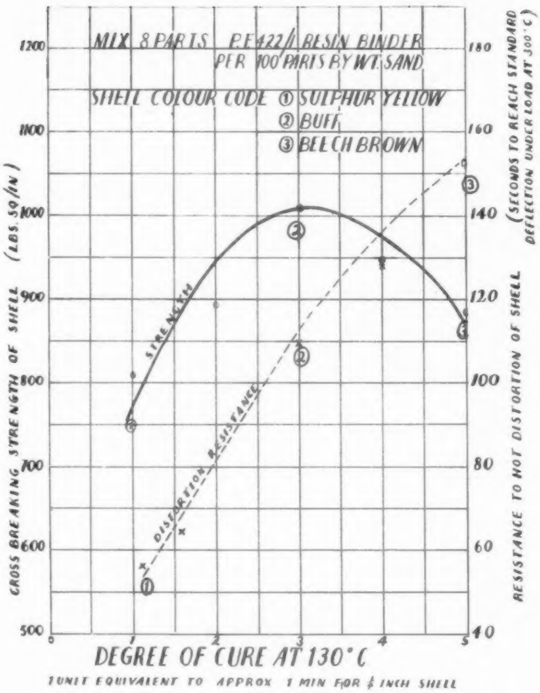


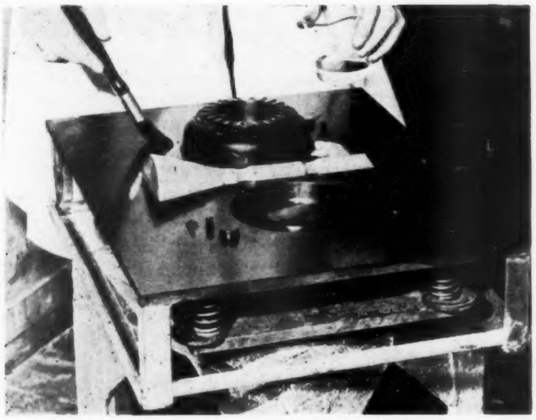
Fig. 3. Effect of time of baking of sand shell on (a) strength and (b) resistance to hot distortion of shell.

Pattern Design

Patterns are preferably of cast iron or steel. Low expansion metals are of advantage and heat-treatable copper-nickel-silicon alloy has been used.[6] Aluminium and non-ferrous alloys are suitable for runners and sprues, but such metals are less desirable for pattern plates due to low heat capacity and tendency towards warping, and for pattern impressions because of low resistance to both mechanical and corrosive damage.

Runners and gates are of first importance. Metal flow across shell surfaces is more rapid than in conventional green-sand moulds due to the smoothness of the shell surface and the heat insulating properties of the shell mould. Runners and ingates should be appreciably narrower for shell moulds than for green-sand moulds of similar capacity. Choking in runners is often desirable to reduce turbulent flow. Wherever possible, mould cavities should be fed in from the bottom so that the metal rises to the cavity. It is found in general that better surface finish results from pouring shell moulds on the flat rather than vertically. In runner systems a suitably placed trough should be provided for dross.

SHELL MOULDING

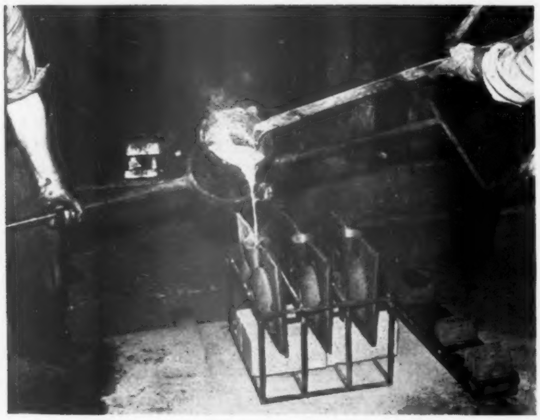


(*a*) first lubrication of pattern with silicone oil.

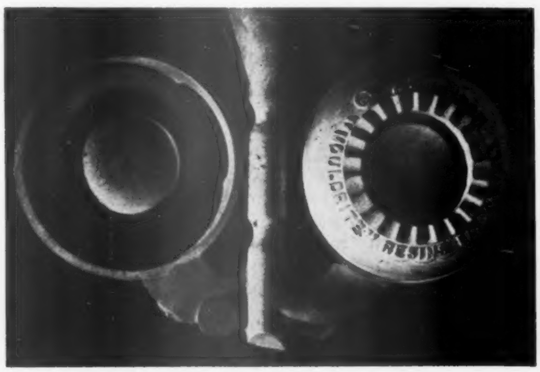
(*b*) removing pattern and biscuit from inverting box.

(*c*) removing hardened shell from pattern after baking.

(*d*) sand shell before assembly.



(*e*) casting aluminium in shell mould assembly.



(*f*) aluminium casting straight from mould.

Ejector pins should be dispersed strategically over the pattern and are preferably mushroom-headed, seating on the pattern. Ejector mechanism using a spring-loaded backing plate has been found satisfactory to ensure even ejection. Alternatively a cam system can be used to raise ejector pins.

Locating pins are normally incorporated in the pattern, these serving the additional purpose of gripping the sand shell to the pattern when it is lifted from the inverting box. Section bars, of approximately $\frac{1}{4}'' - \frac{1}{2}''$ square section, can be fixed to the pattern surface to extend round the perimeter of the pattern; these have a double function by (a) conferring extra rigidity to the shell and reducing distortion and (b) by gripping the shell to the pattern surface during removal from the inverting box.

For casting, shells may be fixed together by bolting, clamping, pinning or glueing, or alternatively by the application of some form of back pressure to the shells. The particular form of fixing must depend on the size and type of work being done. As yet there is no confirmation of the complete superiority of any one method of fixing shells over alternative techniques.

Methods for Producing Sand Shells

For small and medium-size shells, the inverting box is the most important method for formation. The inverting box is in principle a metal or wooden box, open at one end, that holds the sand mix. The heated pattern is clamped over the open end and the box inverted to allow the sand mix to fall on to the pattern face. After a predetermined time, the box is righted, excess sand mix falls back into the box and the pattern is lifted off, with the soft sand shell adhering to it. The pattern and shell are then submitted to oven treatment for a predetermined time at the end of which the hardened shell is ejected from the pattern. The pattern is immediately clamped on the inverting box again and the cycle repeated. The same principle can be used with the pattern clamped and unloaded from the lower end of the box employing a suitable sand trap inside the box. This obviates the necessity for turning the pattern over at the baking stage.

For manual operation an inverting box with a pattern at each end will speed production. The use of a non-inverting box with a retractable bottom allows the sand mix to be forced up against the pattern under pressure. This gives a stronger shell.

Another method of producing the shell, applicable for larger shells, is by hand dispensation. The sand mixture can also be applied to the pattern by blowing, and it is when using this technique that wetting agents in the mix become of value in preventing separation of the lighter resin component from the sand. Cores may be produced by tumbling or blowing the sand/resin mix into a hollow vessel, and apparatus for this process has been the subject of claims.[7] Cores of comparatively large dimensions, and some intricacy, are now being made on a production scale in Great Britain.

Manually operated inverting box/oven systems can approach closely in efficiency mechanical methods for making shells. One system employs a static oven into which the pattern moves on rails, so that on withdrawal from the oven the pattern may be swung directly on to the inverting box which is situated within two feet of the oven; it is not necessary to lift the pattern from the rails if a pivot system is employed. Another system uses an inverting box with the pattern pivoted to the rim, thereby becoming an integral part of the box; in this case a heating hood, employing infra-red or gas heating, moves over the pattern to cure the shell. Where static oven heating is used in manually operated systems, it is desirable to have the heat rising from the base of the oven in order to maintain pattern temperature during shell-making cycles. Multi-shelf ovens are satisfactory in use. It is desirable to water-cool the rims of inverting boxes.

Use of Mechanical Methods

The real future of the shell-moulding process lies in the use of mechanical shell-making methods. To date, two distinctly different types of machines have been developed, i.e., single and multi-pattern machines. In the single pattern machines, a comparatively large pattern is employed in conjunction with an inverting box and in general a hood heating unit that may be electrically or gas heated. The heating unit may be either static or moving.

The multi-pattern machines in general use a static gas or electrically heated oven through which four or six patterns pass in rotation on a circular conveyor system, and work in conjunction with a single inverting box. Each type of machine has its own particular advantages; the multi-pattern machine appears particularly suited to foundries where mixed work demanding some flexibility is required.

In a mechanised shell moulding lay-out which has been described in some detail,[18] a six-station machine produces a 20″ x 30″ shell at the rate of one every 20 seconds. Total direct personnel for the production and pouring of 3,000 shell moulds per day is given as:—

1 sand mixer,
3 shell machine operators,
1 core setter,
1 shell setter and mover,
1 gravel filler,
3 pourers,
3 labourers,
1 mechanic,
1 skip bucket operator,
1 shakeout screen operator,
6 snagging and cleaning,
2 inspectors,
2 supervisors.

Shell Cores

During recent months, interest in the manufacture of cores by shell moulding has increased considerably, not only for insertion in shell moulds, but also for use in conventional green-sand moulding. The advantages of shell cores become most pronounced when relatively thin-walled castings are being poured in which metal-tearing may occur during cooling, or

where breakdown problems are met. At the same time, the economics of shell core usage improves core size increases and over a certain size shell cores are definitely attractive on economic grounds.

The method of making shell cores is essentially the same as for shell moulds, in that a heated pattern, usually in the form of a split core box or mould, is invested with a shell-moulding mix. In its simplest form, a core can be made by filling a suitably lubricated split-core box with the dry sand/resin mixture, allowing to stand for 5-30 seconds depending on the thickness of wall required in the core, then emptying the loose sand/resin mix from the core box back into stock, after which the core box is transferred into an oven and heated for the normal shell-making time. The core box is then split, the core removed, and the same investment process repeated immediately. Blowing methods can be used to fill the core box, but it is emphasised that in order to eliminate the risk of segregation of resin and sand during blowing, modifications to blowing techniques are necessary, in general involving the use of lower air pressures.

A range of cores is now being made by shell-moulding techniques in this country on a production basis, using methods ranging from the most elementary, involving a minimum of capital expenditure, to blowing techniques for the manufacture of cores of some size and complexity.

Casting in Shell Moulds

As a result of the low thermal conductivity of shells, castings from shell moulds are in general characterised by two important properties:—

(a) slower cooling rates in shell moulds leads in general to larger grain size in castings;

(b) considerably less chilling of metal surfaces occurs in shell-moulded specimens compared with green-sand mouldings, this being more emphasised as casting temperature rises.

These properties are influenced by a number of factors, for example, density and thickness of shell and the amount and type of backing material. It follows that thicker shells, also the use of non-conducting backing materials, will tend to reduce surface chilling and give slower cooling with consequent effects on the metal, whereas thinner shells and the use of heat-conducting backing materials, plus artificial cooling, will increase chilling effects. Reference should be made to B. N. Ames' valuable work on this subject.[6]

Aluminium base alloys give sound castings with excellent finish. A wide variety of production castings has been made in aluminium alloy.[19] Shell moulding of this metal appears to have no adverse effects on micro-structure.

Copper-based alloys, for example 88 Copper/10 Tin/2 Zinc gun metal and 88 Copper/5 Tin/5 Zinc/5 Lead leaded bronze, give good castings. Lead sweating has been found to occur in high-lead bronzes, also tin sweating from high-tin bronzes.

Cast iron, including grey, nodular and malleable iron, in general give satisfactory results with very good finish. The position with steels is still obscure. Carbon pick-up is known to occur with low carbon unalloyed steels, but some high alloy steels have been cast successfully. This subject is being investigated at the present time and progress is being made on the production of shell moulds for low carbon steels.

In Great Britain, although the shell process is as yet being operated on a limited scale, a variety of castings is being produced in this manner. Casting has been mainly in iron and aluminium to date, with some brass and bronze, and includes pump base castings, meter casing plates, door handles, propeller support units and impellers in aluminium alloy, also pinnacle nuts in gunmetal[19]; air-cooled engine cylinders and air compressor crankcases, including compressor units weighing 70 lb. are produced, also a cylinder liner casting weighing 200 lb. in iron.[4] A variety of other castings is being made on a production scale. Reference to the literature shows that in the U.S.A. production of shell-moulded components has now reached a significant figure.

Experience is showing that shell moulding is most useful to those industries where long runs of particular castings are required, for example, in the petrol and Diesel-engine industries, but that, in general, short runs are uneconomical due to pattern costs. For jobbing work the process has little value. Where new production is envisaged, both the capital expenditure and floor space required for shell moulding a given volume of work is considerably less than that needed for conventional casting techniques. This is an important consideration where new or expanded foundry production is envisaged.

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THE APPLICATION OF SCIENTIFIC ADMINISTRATION METHODS TO ENGINEERING PRODUCTION

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THIS Paper has as its objective the focussing of attention on a comprehensive global concept of the work of the production engineer, and the scientific administrative methods that he can employ in his quest for increased productivity and reduction of cost.

The underlying philosophy upon which it is based is more concerned with the principles involved, rather than the exploration in detail of the alternatives available and the mechanics of their operation.

National Economics and the Production Engineer

The subject of the Paper is, to say the least of it, a fairly broad one, as I have confirmed for myself during its preparation. I am not complaining; indeed, I chose it for myself out of others that were proposed, for here was an opportunity for me to express myself without any inhibitions or restrictions, on a subject in which you and I as members of the Institution of Production Engineers have mutual interests and, unless I am mistaken, it is a subject that will assume a vital importance for everyone in Great Britain in the not-too-distant future, because it is related to the economic survival of this country.

We, all of us, as engineers, are immersed in our problems, small or great as we believe them to be, and if you are the same as I we have little opportunity for meditation on the major issues of national well-being. We are too prone to leave these matters to others who, to us, appear more competent to worry about them.

Arising out of my own experience, because I have the opportunity of meeting business men from other countries, most of whom are connected with engineering, I am no longer of the opinion that we should let others worry for us. We should start worrying for ourselves and also prepare ourselves for the economic experiences that are almost certainly in store for us. These business men come from Belgium, France, Norway, Sweden, Denmark, Italy, Africa, Australia, New Zealand, Brazil, America, Canada, agents for British engineering products and other goods, buyers coming to this country, visitors on business-cum-holiday trips. All of them at different intervals over a long period, comment not only on the competition we are now experiencing, but on how our competitors are becoming more serious as rivals. The attractions that they have to offer are competitive prices—acceptance of special orders—modern and enterprising design—quick delivery, and extended credit for the buyer for the privilege of his order.

Now we in this country are not generally pessimistic, so to satisfy myself that I was not becoming morbid I contacted a gentleman at the Treasury to ask him what was the Treasury's view on this matter and the following is the climate of opinion as it was expressed to me.

The 1953 Budget provided incentives to industry by releasing purchasing power through the remitting of taxation. As was expected, money flowed more freely but this has not resulted in any marked inflatory or deflatory tendencies. The internal financial situation is stable and satisfactory.

Production has increased during 1952-1953 back to the level of 1951. This is fairly reassuring, but it is necessary to take into account some special trades, e.g. building, which have contributed greatly to the rise in production, and clothing, which has just recovered from previous setbacks. Even more important, the increase in production has not yet been accomplished by a sufficient rise in exports.

The balance of payments is not satisfactory. The increase in production has resulted in additional imports of raw materials and consequently the surplus is much smaller. If we do not earn in our overseas trade a sufficient surplus—which is put officially at £300 million a year—the following consequences must follow:—

(a) we cannot pay our debts;

(b) we cannot make provision for the development of the Commonwealth resources;

(c) we cannot develop our industrial capacity;

(d) we cannot afford to import the raw materials and food to sustain our industry and our population.

There are 50,000,000 people living on this island and failure to export sufficient of our production must mean that the standard of living of the population will be reduced considerably. It may even result in there being insufficient to eat. The ideal solution to this problem is an increase in the volume of production of the "right goods" at the "right time," but ideal solutions in practice have the disappointing habit of remaining ideals.

The Practical Solution

As the ideal solution may never be put into effect I submit that it is a matter of conscience for all production engineers, especially the members of this Institution, to achieve a much larger volume of production and at the same time reduce production costs, with the existing labour force, plant, machinery and equipment.

An analysis of the definition of a production engineer as defined by the Institution makes it quite clear that he is expected to—

(i) have a knowledge of the technology of the processes involved;

(ii) plan the operations relative to the plant and equipment at his disposal;

(iii) provide special purpose tooling as may be required;

(iv) ensure maximum utilisation of direct and indirect labour, plant and equipment;

(v) determine standards of labour performance;

(vi) ensure that quality standards are maintained;

(vii) ensure that cost standards are not exceeded.

This analysis of the duties and responsibilities of the production engineer makes it quite clear that increased productivity is not merely a matter of conscience. There are moral and social considerations that demand that he should bring to bear all the influence at his disposal to persuade management to give him the opportunity of putting into practice the full range of activities arising out of the definition of a production engineer.

Design and Modern Production

The trend in the design of modern consumer technical or scientific products is becoming increasingly complex with the new scientific knowledge applied by progressive product designers. The majority of present day products must be capable of being produced economically by mass production methods, but must still retain the high standards of functional efficiency and external appearance that were obtained under less competitive conditions.

The handicraft arts and the highly skilled craftsmen who practised them have to a very great extent disappeared and in their place we have the research workers, designers, technicians, machine operators and machines. These are the factors that the modern production engineer has to consider and make possible their operation as an effective single purpose organism.

Due to these trends and the demands that are being made upon industry, the traditional production engineer—that speed and feed metal cutting expert and fabricator of metal with nuts, bolts and rivets—has receded into the background.

The Future of the Production Engineer

Considerable progress has already been made by the production engineer with regard to obtaining recognition in the economic and business realms of industry, but he still has a considerable task of reorientating his own outlook relative to present day economic conditions.

The development of scientifically organised production has been a matter of progressive evolution, during which time the production engineering function has made a considerable contribution. But it has not made the contribution it could have made, because it has devoted the majority of its thoughts and energies to the perfection of shop floor techniques and has almost completely ignored the essential requirement of integrating the administrative methods and production techniques which, when combined, become production management.

In spite of their having been neglected, administrative methods have been developed (many of them not by engineers) to such a degree that the production engineer will in the future have to devote as much attention to them as he has in the past to the technologies because, in view of the national economic position of the country, production must be increased through every means available—technical means, technical efficiency, organisational efficiency.

Scientific Administrative Methods

The work of the production engineer is becoming more scientific throughout the whole of industry, and consequently the function now demands the knowledge of management research methods in addition to practical production techniques. He is taking his place in the front line of national management, which is in contrast to his being regarded merely as a

technical expert. A review of the membership of this Institution is sufficient proof of this statement.

The successful production engineer is one who is capable of sound judgement with regard not only to how a product can be manufactured but, in addition, to how it can be manufactured successfully and economically. The reliability of his judgements will be conditioned by the information that is available concerning past performances, present situation and future probabilities.

The first essential to enable reliable judgements to be made is the employment of scientific administrative methods.

The term " scientific administrative method " is one that loosely defines any non-technical method that is employed by the functions of administration—planning and control.

It is a term that is used in connection with all forms of research, investigation and experiment and their processes of analysis, measurement and synthesis when determining the facts of technological phenomena and managerial situations. They substitute the known for the unknown, the constant for the variable, i.e., the establishment of quantitative-qualitative unit standards in terms of which calculations and plans may be made and reasonably be expected to come true.

Organised statistics do not constitute management, which is a matter of personal ability, but they do provide the most important of all aids to sound judgements. Without them habits, custom, inertia and lack of prompt and reliable knowledge will subordinate the personal element. This implies the making of necessary provisions for securing and utilising information for use when required.

These administrative methods can be employed for matters of routine or for special purpose investigations. The activity of their employment for either general or particular purposes constitutes operational research.

Operational Research

Production engineering operational research combines and integrates all the administrative methods that can be employed to enquire into problems arising out of the effectiveness of organisational procedures or production techniques. It gives practical expression to the continuous mental process of seeking for improvement. It is the science of defining causes of inefficiencies and of determining means of correcting them.

The scope of operational research within the individual firm naturally depends upon the nature of the product and the complexity of operations. The benefits to be derived from its application would be much greater if there were a more general recognition and awareness of the alternative administrative methods that are available to be employed as routine tools, or as special purpose instruments of investigation.

In view of this statement, I now propose to review briefly the more important methods in general terms and to illustrate how they are put into effect by a particular company.

Organisation and Classification

The basic fundamental that must be observed to ensure economic operation of any company is a suitable organisation structure and the orderly arrangement of facts and information. This is not a platitude, but a fact that applies to all companies, the only variation arising out of this common necessity being the variation of the degree of complexity and intensity from one organisation to another.

With regard to the organisational aspects of my own company, the principle of " the division of labour " is employed with experts being responsible for specialist functions, the span of control being narrow for each.

The technique of classification that makes practical the orderly arrangement of facts and information is becoming increasingly important in the field of production engineering. The structure of a well-known system with which I am familiar provides scope for future expansion and changing conditions, and at the same time is comprehensive, so that all aspects for an organisation, abstract as well as concrete, are covered. It is a purely numerical system and hence is suitable for punched card methods.

Classification leads directly to simplification and standardisation of design with all its accompanying advantages.

Production Research

The technology associated with the majority of processes is in a continuous state of development, and in view of the rapid and ever-increasing progress that is being made with new techniques, it is difficult to imagine how maximum efficiency can be achieved without some degree of production research being employed as a continuous process, examining every possibility of applying new knowledge to old techniques and new techniques to replace the old.

In many large companies, production research has developed into departments similar to technical research, but this does not necessarily mean that they have a monopoly of the benefits that may possibly accrue, nor does it mean that production research demands extensive laboratories involving the use of extremely complicated equipment.

There are many excellent jobs of research being done by very normal individuals who would consider it pretentious to call their natural inquisitiveness, research. They are usually keen observers who can recognise possibilities relative to their activities.

Product Design

At the beginning of this Paper I made reference to the fact that the production engineer has already made some progress in obtaining recognition in the business realms of industry. This I believe is due more to the outstanding abilities of the comparatively few individuals who have made the grade, than to the recognition of the centralised functional pivot of the production engineering function by the directors of industrial undertakings. I also made reference to the fact that the production engineering function has a much wider influence on company operating performance than has been appreciated in

the past. This is particularly true in connection with product design.

The need for a practical economic outlook is greater to-day than ever before and, in consequence, there should be a much greater degree of co-operation between the product designer and the production engineer.

The benefits that are the natural outcome for this functional relationship always outweigh the time spent in discussion and re-design on the part of the product designer. We are continually being warned that international competition in the markets in which we sell our products is becoming even stronger, and that many of the countries to whom we now export are becoming increasingly self-sufficient. Is this not sufficient warning of the shape of things to come ?

The policy under which I am employed is one that makes it an obligation of the production engineering function to be continually looking over the shoulder of the product designer during the period of product design, and maximum bilateral co-operation exists resulting in wider manufacturing tolerances and ease of manufacture when it is functionally permissible.

This policy has not resulted in a decreased standard of production functional performance; the contrary is the case.

The combination of classification, simplification, specialisation and standardisation has resulted in a range of products that is perhaps unique from the point of view of the variations that are possible within each range.

Methods Engineering

Methods engineering is the term that is becoming more widely used to convey the global concept of the work that is the responsibility of the production engineer.

The interpretation of the duties and responsibilities of the production engineer, to which I have previously referred, places upon him the obligation of having a working knowledge of all the administrative methods that are the subject matter of this Paper. Those that are employed more generally are method study and work measurement, both of which were among the earliest to be developed, but they are not yet employed universally, and in some instances when they are, they are not employed as they were intended.

Method study is an operational research tool that can be employed to enquire into all the fundamental factors of production. With regard to work measurement, it is the production engineer's measuring tool. When it is employed correctly it provides a means of evaluating all industrial activities in quantitative qualitative units for the determination of standard performance values.

The success and effectiveness of any investigation undertaken can only be relative to the soundness of the data obtained during the investigation. This being so the methods employed to obtain the data should be as scientific and as thorough as possible. It was to satisfy these requirements that the concept of the work unit was established as a reasonably consistent standardised unit for the evaluation of the labour content per unit of production.

Production Control

Referring back to the problem of international competition and the warnings we have received from time to time with regard to the prospects in the future, we should not overlook the fact that customers and agents overseas for British products complain bitterly now of extended delivery quotations and of broken promises. This state of affairs will have repercussions in the future which we will regret.

In this connection the production engineer should be aware of his formal and moral responsibilities, because while it is true that methods engineering decides what is to be done and where to do it, production control cannot decide when it shall be done until it receives the basic operating data from the methods engineering department.

In my own case the production control department endeavours to give the best service possible to customers, consistent with available machine capacities and methods that have been calculated by methods engineering to secure lowest possible costs.

Although service to customers cannot be evaluated precisely in financial terms it is, nevertheless, accepted as having considerable profit and loss potentialities. This is one of the reasons why there is a continuous process of investigation in operation to improve production methods that will reduce the production cycle of batches passing through the production sequence of operations. Due to the employment of this policy the importance of production research will be readily appreciated, because there is a continuous stream of possibilities to be investigated.

A Progressive Outlook

In recent years, the aspects of business administration have become more complex and, due to problems arising out of company taxation, very frustrating. This state of affairs, together with the uncertainty of the future, may in some companies have the effect of retarding the introduction of some of the newer techniques that have been developed for use by the production engineer, such as electronics, radio isotopes, R.F. induction heating, and so on.

The natural tendency of the production engineer with a progressive outlook is to keep ahead by adopting the latest improvements in equipment, new machine tools or new techniques which can be proved to have cost-cutting possibilities, but because of the reasons I have just stated, he may not be in a position to take advantage of them.

Frustration is no excuse for production inefficiency. Irrespective of the production plant available, the best results of operation will only be achieved when production engineers employ a constant operational research attitude and a continuous study of their problems, discovering for themselves where improvements can be made with the existing plant, equipment and machine tools. This plan is not only effective, it is one of the most certain safeguards against making premature purchases of capital equipment, which may end in costly charges for obsolescence.

The most effective tools to be employed in the works departments before major capital decisions are made are method study, work measurement, and quality control and the resultant facts appertaining to the present effectiveness of men, materials, machines and their future potential.

Personnel Management

In the March 1954 issue of the Institution's Journal, Sir Vincent Tewson, C.B.E., M.C., General Secretary of the Trades Union Congress, contributed to the series "An Expansionist Policy for Production." His article commenced as follows:—

"Emphasis has already been laid in this series on British industry's need for more capital investment and a widespread and more extensive use of production and work study.

"Increasing the productiveness of individual effort with the aid of more and better machinery and more effectively employing existing production resources—including British workpeople's skill, initiative and experience—is the rational way of improving our economic and social lot. Given the raw materials and the equipment, there is sufficient willingness among all in industry to work enthusiastically towards raising productivity and sustaining our position in competitive markets, which play such a vital part in maintaining a high level of employment."

Sir Walter Puckey, in a previous issue of the Institution's Journal, said: "When we speak of production we really speak of the men who practise it."

Sir Vincent also stated: "It is on the shop floor, after all, that management policy seeks expression and where it stands or falls, not only on its technical merits but also on its reasonableness and acceptability—on its 'human' content."

These statements were made by the two heads of the two most influential factors of production, i.e.,

The Institution of Production Engineers and
The Trades Union Congress.

The production engineer's contribution to the personnel function and the human content of production is an indirect responsibility and it arises out of the application of:—

Job evaluation
Incentives
Training
Health and safety.

The principle that gives expression to job evaluation and which I suggest is "that individuals should be given the opportunity to express themselves through the degree of skill that they possess and that they should be remunerated in proportion to the job demands of skill, effort and responsibility."

I recommend also the incentive plan which has as its basic fundamental of policy "that 100% bonus should be paid for 100% fully sustained effort." Speaking in general terms, the production engineer could, if he were given the opportunity, reduce the anomalies that are present in many wages structures and incentive plans. If he *were* given the opportunity he would be kept busy for a very long time.

Quality Control

The need for the maintenance of quality standards admits of no argument. In the first instance, quality increases sales appeal and, in the second, quality contributes to the maintenance of consumer satisfaction.

Arising out of this introduction to quality control, we are reminded that industry is carrying the burden of a subjective non-productive function that exists in many cases for the purpose of determining how large a proportion of production is found to be defective, as opposed to an objective assurance that production quality is satisfactory. While it is true that quality standards should be maintained and as such quality assurance is worth paying for, the cost of sorting out the good from the bad, *after* the event, is much too high a price to pay.

There are, generally speaking, two aspects of quality, i.e., finish and measurement. In many firms production and scrap costs are too high because of the idealistic standards of finish that are demanded by inspection departments. With regard to the measurement aspect, much additional production and scrap cost is incurred due to the close tolerances specified, by comparison with those that would be functionally suitable for product performance or that are too close for consistent attainment by the machine.

The statistical methods of quality control have much to commend them, as they are employed objectively for the prevention of scrap and for quickly determining if the machine is economically capable of producing in accordance with the quality tolerances specified.

These statistical methods of quality control have long been employed as special tools for operational research into problems of quality; they have been employed as routine administrative methods in many firms for many years. They constitute not only the means of controlling quality during production, but also provide the basic information upon which the foundations of the quality standards of products are built.

Quality control chart methods have three important virtues that commend them in the quest for increased efficiency and reduction of costs:

1. the prevention of defective work and scrap;
2. the reduction of inspection costs;
3. the improvement of the interest of the machine worker, due to the psychological challenge implied in the charts and as a means through which they can express job satisfaction.

Performance and Cost Control

It was stated earlier in this Paper that the successful production engineer is the one capable of sound judgement with regard not only to how a product can be manufactured, but, in addition, how it can be manufactured successfully and economically.

To keep the production engineer informed of variations from standard, a regular flow of prompt

and reliable information must be maintained. This flow of information enables him to make prompt routine decisions and to initiate special purpose operational research investigations as may be necessary. The information is normally provided by the works cost department which is, metaphorically speaking, midway between the practical aspects of production and the financial accountant, acting as a control or regulating function before the final operating figures are recorded by the financial accountant as a historical record of success or failure.

The production engineer of to-day, in addition to being a technician, is expected to be a practical economist striving always for maximum volume of production at minimum unit cost. This can only be achieved if he employs the principles upon which efficient management relies, i.e.:

(i) the planning of performance;

(ii) the determination of standards of performance;

(iii) effective control during performance;

(iv) the comparison of actual to standard performance;

(v) the analysis of variants to provide guidance for future operations.

All forms of industrial activity can be subjected to this form of treatment. It has been stated that standard performance and cost control could be applied successfully only in those industries employing highly repetitive operations. It has been proved conclusively that all forms of manufacture can employ standards successfully.

The setting of standards is primarily a process of engineering that endeavours to determine the lowest possible cost consistent with the quality and service requirements of the business.

In addition to keeping the production engineer informed, considerable benefits are secured when the operating results are published and distributed to the responsible departmental supervisors. These benefits arise from the psychological effects produced and the stimulation of cost consciousness.

Conclusion

In nearing the end of this Paper I would like to remind you that the ultimate purpose of the objective of all the scientific administrative methods discussed is the maximum effectiveness of management, maximum production of saleable products, with existing resources and minimum unit cost. The principles of the methods are already well known, but as yet they are not applied universally. Indeed, there are many firms that do not employ any of them.

Some of them are more suitable as routines, others as the basis of operational research investigations.

The following definition of operational research, as set out in " The First Report of the Committee on Industrial Efficiency," provides a concept of the activity and an indication of its importance:

" Operational research may be defined as the use of the scientific method to provide executives with an analytical and objective basis for decisions.

" This type of research has the advantage that it can be made to produce results in a much shorter time and with much less expenditure than fundamental or purely technical research. It is appropriate at a number of different levels; at the national level, for industries and in individual firms."

During the War, some of the most eminent scientists were employed in operational research. These scientists, through the application of scientific methods, were able to determine how and where the nation's manpower and resources could be employed to the greatest advantage.

At this stage, when production engineers should be applying their energies to the economic problems with which this country is confronted, it is important to consider whether sufficient use is being made of operational research. It is almost superfluous to say that the need for greater industrial efficiency is essential if we wish to be able to export at least at our present rate and to maintain our present-day standard of living.

We are continually receiving warnings with regard to the problem of international competition and the balance of payments. They are emphasised by complaints of customers and agents overseas of extended delivery terms, of fluctuating price quotations, of lower quotations from other countries and failure to keep delivery promises. This must have most regrettable repercussions in the future. In conclusion, I submit that scientific administrative methods, employed on a much larger scale, would increase industry's operating efficiency. Efficient production engineering in all spheres of production is a vital necessity for the economic survival of the whole nation.

BIRMINGHAM ELECTRONICS EXHIBITION

An Exhibition entitled " Electronics at Work " has been organised by the Electrical and Electronics Group of The Scientific Instrument Manufacturers Association, and will be held at the Chamber of Commerce Hall, New Street, Birmingham, on 23rd, 24th and 25th November, 1954.

The Exhibition will be opened at 2 p.m. on 23rd November by the President of the Institution of Production Engineers, Sir Walter Puckey, introduced by the Lord Mayor of Birmingham. Free admission tickets are obtainable on request from S.I.M.A., 20, Queen Street, London, W.1.; the Chamber of Commerce, New Street, Birmingham; the Birmingham Exchange and Engineering Centre, Stephenson Place, Birmingham; and the City of Birmingham Information Department, Corporation Street, Birmingham.

ABSTRACTS

PROGRESS IN AUTOMATIC PRODUCTION

by H. L. Waddell

Editor, Factory Management and Maintenance

(Abridged from a Paper presented at the Annual Meeting in New York, in 1952, of The American Society of Mechanical Engineers and published by kind permission of the Society)

BEFORE progress in automatic production—or automation—can be assessed, it is necessary to know just what is meant by automation. There can be no doubt that the factory which will run *ad infinitum* without human intervention is an example of automation, but this is hardly a practical basis for a definition. But since our purpose is to measure progress, we may reasonably accept this as the ultimate in automation. The present situation may then be examined to determine these things:

1. the mechanical requirements of ultimate automation;
2. the managerial requirements of ultimate automation;
3. the socio-economic requirements of ultimate automation.

In each case we can quite readily establish where we stand today in relation to fulfilment of the requirements for ultimate automation. Somewhat less readily identified—and certainly more difficult to evaluate in terms of their implication for the future—are those factors which will tend to promote, or impede, progress toward fulfilment of the requirements for ultimate automation.

Finally, it is desirable to examine the basic concept of ultimate automation and suggest a new pattern of intellectual orientation toward the application of the techniques of automation.

Mechanical Requirements

Ultimate automation, as we have defined it, calls for uninterrupted manufacture of acceptable productions without human intervention. To meet that specification on a factory-wide basis, we must first apply ultimate automation to the individual processes in the plant, then integrate them in a co-ordinated system, and finally apply a single overriding control. At each stage, the required elements of control are the same; a closed-loop or feed-back system is needed.

The commonest form of feed-back system is the human being, and when it comes to making a correction in the processes, there are two possible approaches. If an error has been anticipated, the human being can be told what to do when and if it occurs. But if the error has not been anticipated, the human being must begin to use his powers of reason and judgment. This is beyond the limit of "mechanical brains" and hence represents the present limit of feed-back control and of automation.

Probably it would be possible to build a control device that would anticipate every possible process condition. As a practical matter, we know that somewhere a point is reached beyond which it is cheaper to employ human agents. For most industrial applications, the cost of ultimate automation is very high in relation to the present cost of human labour.

As a consequence, automation is applied today primarily in two situations:

1. where the "type of human labour" required is such that an adequate supply does not exist, at any price. Such applications are generally in connection with engineering, research and design problems, rather than production processes;
2. where the "nature of the process" is such that it is literally impossible for human beings to exercise adequate supervision and control. Production of radioisotopes and petroleum refining are perhaps outstanding examples of such large-scale operations.

A third and rapidly-growing area of applications of automation is where the quality requirements of the end product are tight. Maintaining fine

tolerances is a job for which feed-back control is admirably suited, and it is here that automation shows to its greatest economic advantage. It would seem that this is the big opportunity for automation in the near future. It is the area in which the economics of automation are most favourable, or at least most readily demonstrable, and at the moment demonstrability is the biggest stumbling block to automation.

Managerial Requirements

Managements must become convinced that ultimate automation is an economically sound investment, and most managements are not yet so convinced. The dollar cost of labour has risen so sharply in the past 20 years that management today is emphasising reductions in labour cost almost to the exclusion of everything else. This is bringing a twofold result:

1. substitution of machines for muscle jobs (which in itself is not automation) is increasing the demand for skilled workers and technicians, in proportion to our total work force, to the point where a "shortage of skills" is becoming one of our most acute problems;
2. despite full employment in all but a few industries, some labour unions are beginning to protest against the advent of new machines that create "technological unemployment". Management persistence in viewing automation as a "labour-saving" device is encouraging such attitudes by unions.

But even where management is willing to look beyond possible labour-saving and assess the largest advantages of automation, many managers remain unconvinced. A common complaint is that the machines are so complicated that the maintenance cost would be exceptionally high.

It is true that automation will make maintenance most difficult. Higher skills, better organisation and more preventive maintenance will be needed, but the burden will not be killing. For proof, management has only to look at the petroleum industry. It is highly automatic. Its maintenance problems are tremendously complicated. But its total labour cost as a percentage of sales is the lowest of any major industry in the history of the world.

There is one more "attitude" which will be required of management before we reach ultimate automation. This is a realisation that automation is possible, and not precluded by the nature of major processes and operations.

Technical Know-How

The technical know-how of automation exists. The only question remaining for management is whether it is economically justified in a specific instance, and whether management is prepared to make certain "collateral changes", necessary if full benefit is to be gained. These changes include a willingness to overhaul the very structure of management itself, because the typical management hierarchy we know today does not lend itself to supervision of an enterprise which has reached, or is approaching, ultimate automation. It is too slow and cumbersome. It provides for specialists, but does not put them where they will be required by automation; it breaks up specialities into units or cells, instead of co-ordinating them into closely welded, smoothly functioning teams.

Further, this "line" organisation of management breeds men who are equipped to manage a particular speciality, not men who are adept at co-ordinating the activities of specialists in many different fields.

We are fast approaching the time when the engineering executive will be an engineering "generalist", that is, a specialist in administration with enough background in many phases of engineering to be able to understand and work with engineering specialists in every field. The problem for management will be one of spotting potential engineering generalists early enough to be able to move them around and thus prevent their becoming over-specialised.

Socio-economic Requirements

Will automation cause a disastrous economic revolution? The Author disagrees with those who believe it will. It is thought that continuation of two well-established historical trends, plus the existence of a very inefficient distribution system, will prevent it. These trends are:

1. with only occasionally temporary setbacks, America has had a continually rising standard of living. As the trend continues, we will consume more goods per person. That, combined with a rising population, will provide a market physically capable of consuming virtually anything and everything even ultimate automation can produce.
2. apart from War-time conditions, the work week has been getting progressively shorter. Today it is little more than 40 hours, compared with 68 hours in 1875 and over 50 hours a mere quarter-century ago.

As automation takes hold, a shortened work week will mean relatively little in the manufacturing industries. But a slight drop in the work week in other industries will bring a sharp rise in the demand for workers.

Referring to the distribution system, the apparently simple act of moving goods from the producer to ultimate consumer is tremendously complicated, and places an almost fantastic strain on our manpower. Well over 2,000,000 people are employed full-time in long-distance moving of goods and to this figure must be added all the people employed in making local deliveries.

Then we have all the people engaged in running the retail and wholesale establishments themselves. Even if automation devices displaced all the book-keepers and accountants, the figure would still exceed 5,000,000.

Certainly the advent of automation is going to mean lower costs, and these lower costs will mean more real purchasing power and, therefore, more

goods produced through lower prices, or higher wages, or both. It is an "economic feed-back control".

If ultimate automation of every major factory were to arrive in a short span of time, the dislocations would certainly be serious. But it is obvious that it cannot take place in every company at the same time, so it can be expected with confidence that the "economic feed-back control" within our competitive system will prevent major dislocations.

An additional factor that will play a definite part within the next decade is the growing number of pension plans with enforced retirement at age 65, which will tend to take people out of the job market.

At the other end of the age scale, we find young people staying at school longer, which means a smaller percentage of job seekers. The trend toward longer schooling will be accelerated by the demand from industry for higher skill and education. Also, the possibility of a universal military training law that would further delay entry of youngsters into the labour force cannot yet be discounted entirely.

All these factors would tend to lessen any dislocating consequences of automation, which leads to the question: "Why aren't people doing it?" The largest single answer is: "A lack of realisation that it *can* be done". This lack of understanding is most pronounced in the industries making discrete units, and rises from the failure of engineers and managers in these industries to regard their whole manufacturing process as essentially the same as the continuous flow of the chemical or petroleum industries. They should remember that 50 years ago these industries, which we think of naturally today as continuous, were using strictly batch processes to turn out barrelfuls. Simple investigation and comparison will prove the analogy.

But it is believed the big turn has come in industrial thinking. The conception of automaticity and flow-processing making "things" is fast gaining acceptance in industries and among managements where it was considered impractical only a few years ago. Furthermore, economic and social forces are working strongly in favour of automation.

The result is almost certain to be an era of rapid evolution and progress toward the highly automatic plant—the factory in which mechanisation will supplant not only men's and women's muscle power, but also their routinised sensory perception.

(*The full text of this Paper is available on loan to members from the Hazleton Memorial Library.*)

THE FUTURE OF AUTOMATIC MACHINERY

by Norbert Wiener

Department of Mathematics, Massachusetts Institute of Technology, Cambridge, Mass.

(*Abridged from a Paper presented at the Annual Meeting in New York,* 1952, *of The American Society of Mechanical Engineers and published by kind permission of the Society*)

MACHINES were primarily devices for replacing human power and energy, rather than what they have since become—devices with a modicum of discriminatory judgment of their own. While it is true that the seeds of modern servo-mechanism were in Watt's ball governor for the steam engine, and that the beginnings of the technique of computing machines existed over two centuries ago, neither the servo-mechanism nor the computing machine could be more than a sporadically useful device until the ripening of the modern techniques of electrical control and amplification, both dependent on the existence of such devices as the vacuum tube, with its simplicity of structure, its cheapness, and its extreme economy of power.

The first really good tryout of long chains of control mechanisms dependent sequentially upon one another has taken place in the construction of high-speed digital computing machines. While the earliest models of these were primarily on a mechanical basis, they have been so far superseded in speed by electronic machines of comparable reliability that the mechanical devices, except for very special purposes, are on the verge of obsolescence. We thus possess a well-developed technique of devices which make yes-or-no decisions on the basis of previous decisions according to a scheme given in advance, in much the same way as the human brain, and we must consider other devices of this sort as well within the range of possibility.

Brain versus Machine

In making this comparison, however, it must be remembered that the number of switching devices in the human brain vastly exceeds the number in any computing machine yet developed, or even thought of, for design in the near future. Even when the transister is so perfected that a satisfactory computing machine can be made out of transisters instead of vacuum tubes, we shall still be far from the compact and manifold complexity of the brain. On the other hand, the vacuum tube already has far outstripped the corresponding nervous mechanism in speed, and probably in reliability of action. This power of the vacuum tube to work on a time scale much smaller than that of the brain, gives back to the computing machine a measure of the efficiency lost by its coarser spatial grain.

The storage of information in the best computing machine yet thought of does not compare with that of the brain, which is at its best in the performance of operations involving a great deal of stored information and a very complex synthesis of this information. The computing machine or factory-control machine, on the other hand, is at its best in the speedy and accurate performance of relatively simple operations.

The success of the computing machine in the treatment of arithmetic is in supreme contrast to our failure to reduce moral aesthetic judgments to any simple method of coding. To be an art critic requires a vast array of cultural experience, historical knowledge and emotional scope and integrity. The number of yes-and-no decisions before it is possible to begin such a task is so enormously greater than the number of yes-and-no decisions for the postulates of a very complicated mathematical system, that all comparison is utterly ridiculous.

Human Values and Characteristics

I cannot see that the machine for the translation of one language into another is imminent, or that we are near a machine which will take in spoken language and give out a typewritten text, or *vice versa*. Translation machines involve the transference machinery of human values, human characteristics of learning and the like, and thus involve the attempt to replace the brain by the machine just where the brain is at its best and the machine is at its worst. I do not doubt that machines can be made to learn, and even to evaluate, but to make them do so after a specifically human pattern involves much more precise knowledge of the human system of evaluation and methods of learning than, I imagine, is now in the hands of the constructors of cybernetics machines or, indeed, of anyone else. These same difficulties will militate against the perfection of the art of cataloguing and cross-reference-making by machine.

I bring up these shortcomings of the linguistic and intellectual use of manufactured apparatus to define and mark off these fields in which mechanical apparatus is already, or threatens to be in the near future, the competitor of the human worker. There still exist factory tasks in which human beings are used for discrimination instead of for power, but in which this discrimination is on such a low level that it represents an employment of human faculties almost as imperfect and uneconomical as that of the galley slave. In many cases, the over-design of the human mechanism used is as gross as if we were to adjust the degree of opening and closing of a barn door by an interferometer.

In a factory in which the greater part of the employees perform routine tasks and management pays attention solely to technical operations, there is a great analogy with the team of semi-skilled computers presided over by a mathematician, the analog of the latter being the "efficiency expert", of old disrepute, who decides on the general pattern of work and details how it is to be done. The employees of such a factory are used only as effector organs of the superhuman mechanism, with its brains elsewhere in the organising staff. Thus the task of replacing these workers by automatic machinery is not the question of replacing so many men, but rather half-men, or quarter-men, or even hundredth-men. Under these conditions, the machine which performs tasks laid out without any regard for the psychological and sociological aspirations of man could become a real competitor of the human worker.

Dangerous Conclusions

From this fact it is possible to draw false and dangerous conclusions, that the machine is rendering the human being obsolete. This view is a grim reminder of past errors, and neglects the work of such management leaders as Gantt and the Gilbreths, who provided techniques which recognised the potentiality and dignity of man's hands and brain. The automatic factory demands managerial personnel who recognise their social responsibilities as well as their economic responsibilities. Today, progressive management thinking denies that man himself is becoming obsolete wherever the machine supersedes him in the routine performance of routine tasks.

If we accept the primacy of man over his means of production, there is no reason why the age of the machine may not be one of the greatest flourishing of human prosperity and culture.

(The full text of this Paper is available to members on loan from the Hazleton Memorial Library)

(concluded from page 600)

Lord Halsbury's words batter their way into novelty, through novelty and out again the other side of novelty to new fields of standard practice dominated and controlled for the future.

"May I express on behalf of myself and all your guests our best wishes for the development and success of your thriving Institution. A small thing, perhaps, but one in which I am extremely interested, is the liaison between you and the War Office. I happened to be the Director responsible to the then Q.M.G. for the formulation of R.E.M.E. and I am glad to know that the liaison between your Institution and R.E.M.E. is steadily growing and I hope that both the men in uniform and those in industrial grades will benefit thereby."

After thanking Lord Sempill for so ably stepping into the breach, Mr. G. R. Pryor, Chairman of Council, said:

THE Institution is second to none in the facilities which it provides for and the attention which it gives to the education of its younger members, and the keeping up to date of the more senior men in those sciences and technologies appropriate to the objects for which the Institution exists. We have, however, a problem which impinges on it more, perhaps, than on most professional institutions, because our day-to-day work has a greater managerial content.

An Increasing Problem

"Fifty years ago there used to be a common saying amongst the Sheffield steel magnates that their two greatest problems were what to do with their sons and what to do with their rubbish. One of the problems which to-day faces all expanding and progressing companies is what to do with the executive who has been with them for twenty or thirty years, who has given loyal, conscientious and hard-working service to his company, but who has failed to grow with his job and who is now a brake on progress. Those who have read "Slide-Rule"—the autobiography of the man who, after helping to design the airship R.100, started a company, Airspeed, in a very small way, with a capital of only £5,000, and saw it grow to very considerable proportions, until in recent years it was taken over by Handley Page—will remember that he faced that problem in an acute degree, and as managing director he felt compelled, rightly or wrongly, to dispense with the services of some of the pioneers who had given him yeoman service in the early days, until finally he was handed the same cup of tea by his own board, and his own services were dispensed with.

"Attendance at the functions organised by the Institution is the best possible insurance policy against anything of that kind happening to anyone. I do not think it matters what the technical content of the occasion is; what matters is that one's mind shall be given a jolt, one's way of thinking widened and one's mental horizon stretched, and above all that one should be conditioned to accept change. It has been said that if one were asked to epitomise in one word the characteristics of the age in which we live, the word would be "change."

The Eternal Truths

"That, however, is only part of the story. Change there has certainly been in all the paraphernalia of living, but human nature itself has not changed. Professor Pollard, the historian, once said that science represented the element of change in human affairs. Its truths were never static. Art and philosophy represented the stable elements; their truths were eternal. Thus, if Aristotle came back to earth he would have to sit at the feet of any first-year science student; but if Plato and Socrates returned, the most eminent philosophers and humanists of to-day would be glad to sit at their feet, for the eternal verities never change.

"The particular assignment of the production engineer is to apply the brainstorms of the scientist, the designer, the statistician and the accountant to inanimate matter, through the agency of human beings. Production engineers are as much concerned with the processes of human misunderstandings, foibles, prejudices and jealousies as they are with the sort of things that concerned Euclid, Newton, Stephenson and Ampère. They are as much concerned with human stresses and strains as with mechanical ones, as much concerned with the antics of their fellow men as with those of the atom.

"I make no apology for ringing the changes on this theme on any possible occasion, because there is no problem facing Western civilisation greater than this: how do we increase the number of men in that élite corps who, by a subtle process of example, persuasion and compulsion are able to get other men to do what they want them to do? In other words, how is it possible to train for leadership?

"The attributes of leadership are somewhat intangible. They have not yet been codified into any curriculum. They are not susceptible to assessment by any formal examinations. There are, however some things which can be done, and the present Dinner is one of them. Each year, as its date approaches, the thoughts of some of us turn to that passage in Ecclesiasticus which begins: "Let us now praise famous men." This evening we had hoped to have the opportunity of absorbing some of that essence of ability which has made Sir Ronald Weeks the man that he is. We have been disappointed in that, but we are grateful to him for writing the address which has been read to us".

NEW BUILDING FUND APPEAL

Since the publication of the last list, donations have been received from the following subscribers. (The list was compiled for press on 18th October, 1954.)

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"MAXIMUM EX MINIMO"

The Institution has been informed by Mr. E. G. Brisch that in his Paper, "Maximum ex Minimo", which appeared in the June Journal, he inadvertently omitted to acknowledge the assistance received from Messrs. Compagnie Parisienne d'Ingéniers-Conseils in Paris, in preparing the material for publication.

Mr. Brisch expresses sincere regrets for this oversight, which was entirely unintentional.

INSTITUTION ANNUAL DINNER

The Annual Dinner of the Institution, held this year at the Dorchester Hotel, London, on Friday, 8th October, was attended by 520 members and guests.

Lt. Gen. Sir Ronald Weeks, K.C.B., C.B.E., D.S.O., M.C., T.D., who was to have been the guest of honour, had the misfortune to be taken seriously ill with influenza a few days beforehand, and was unable to attend. During the evening the President, Sir Walter Puckey, on behalf of the members and guests, sent Sir Ronald a telegram conveying warmest greetings and best wishes for a speedy recovery.

Sir Ronald had already prepared the main substance of his address, which he was to have given in response to the toast of "The Guests", proposed by the President, and it was read on his behalf by the Rt. Hon. Lord Sempill, A.F.C., Hon. M.I.Prod.E., a Past President of the Institution.

During the evening the following Institution Awards were made by the President:

The Viscount Nuffield Paper, 1953. Lord Sempill, who gave this Paper, entitled "Productivity —Are We On The Right Road?" had chosen an antique desk which had once belonged to William Gladstone, and he was presented with an engraved plaque to be placed on it.

Institution Medal for the Best Paper presented by a Member, 1952/53. Mr. F. G. Woollard, M.B.E., M.I.Prod.E., for his Paper entitled "The Advent of Automatic Transfer Machines".

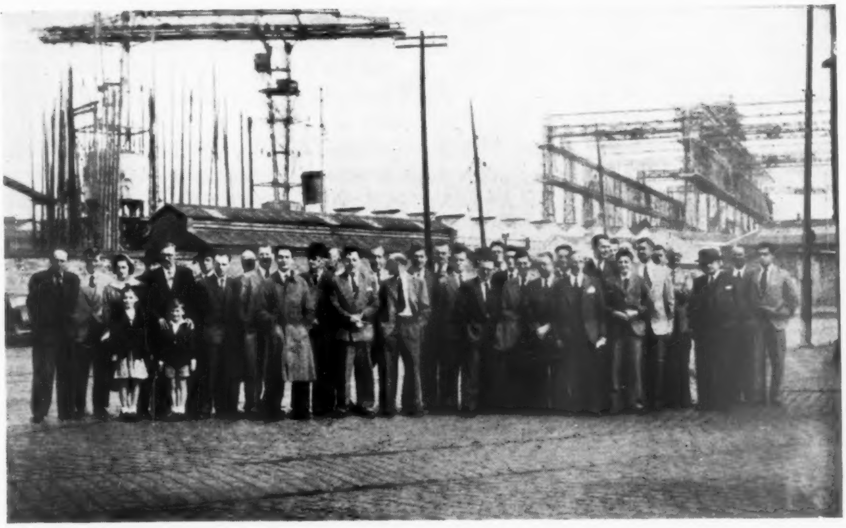
Lord Austin Prize, 1953 (for the best essay by a Graduate). Mr. D. Whitehead, Grad.I.Prod.E., for his essay entitled "Incentive Systems".

The President also referred to the following awards, which were made *in absentia:*

The George Bray Memorial Lecture, 1953. A presentation of a silver cigarette box to Sir Harry Pilkington for his Paper entitled "The Application of Modern Production Engineering Methods in the Glass Industry".

Courtesy "South Wales Evening Post"

The President of the Institution met leading local industrialists at a dinner given in September last by Captain H. Leighton-Davies, C.B.E., J.P., to inaugurate a new series of lectures, on the theme of "More for Less", which has been organised by the West Wales Section. This photograph shows Captain Leighton Davies, who is a past President of the Section, with his guests. In the front row, from left to right, are Mr. J. Lee, Metal Box Company; Mr. R. B. Southall, National Oil Refinery; Captain Leighton Davies; Sir Walter Puckey; Mr. A. E. H. Brown, Transport Commission; and Mr. W. H. Bowman, South Wales Aluminium Works. Also included are Mr. H. H. Swift, Transport Commission; Mr. J. S. Hopkinson, Anglo-Celtic Watch Company; Mr. A. Katz, Mettoy, Ltd.; Mr. Maynard Davies, National Coal Board; Mr. Arthur Parsons and Mr. T. G. Wittam, Metal Box Company; Mr. C. H. Cunniffe, M.B.E., and Mr. H. P. Sanderson, I.C.I. Metals. Mr. Sanderson is Hon. Secretary of the West Wales Section.



This photograph was taken outside the main gate of Harland and Wolff's Queen's Works at Belfast, during a recent visit by members and friends of the Northern Ireland Section. The party includes Mr. John Ringland, Section Chairman; Mr. H. F. Spinks, Section Vice-Chairman; Mr. R. Cairns and Mr. S. Annesley, past Section Chairmen; and members of the Section Committee.

Sir Alfred Herbert Paper, 1954. A presentation of a silver tray to the Right Hon. the Earl of Halsbury, F.R.I.C., F.Inst.P., for his Paper entitled "Some Problems of Higher Technological Education".

Schofield Travel Scholarship, 1954. Awarded to Mr. W. R. Bailey, Grad.I.Prod.E.

Hutchinson Memorial Award, 1952/53 (for the best Paper presented by a Graduate). Mr. L. K. Lord, Grad.I.Prod.E., for his Papers entitled "The Nature of Tungsten Carbide" and "The Technique of Carbide Tooling".

(Extracts from the speeches made at the Dinner appear on pages 597/600, and 651/652*).*

news of members

Mr. R. Ratcliffe, M.B.E., Member, Vice-Chairman of the Institution's Education Committee, has recently relinquished the post of Superintendent of the Royal Ordnance Factory, Nottingham, on his appointment as Director of Instrument Production in the Armament Supply Division of the Ministry of Supply.

Mr. G. E. Townsend, Member, has recently taken up an appointment with Brown Lenox & Co., Ltd., Pontypridd, as a Methods Engineer.

Mr. John H. Bostock, Associate Member, has taken up an appointment with the English Electric Co., Limited, Stafford, as a Product Development Engineer.

Mr. Joseph Doyle, Associate Member, has relinquished his appointment of Lecturer at the Morris Institute, Preston, and is now Lecturer in Production Engineering at the Birmingham College of Technology.

Mr. A. C. Foskew, Associate Member, who is very well known in the North Eastern Counties, has recently relinquished his position with White's Marine Engineering Co., Ltd., and has now joined the staff of Dowding & Doll, Limited, London, as Technical Sales Representative for Durham, Westmoreland, Cumberland and Northumberland.

Mr. N. Greensmith, Associate Member, is now a Director of Linden Engineering Company Limited, Bradford.

Mr. Owen Harris, Associate Member, formerly Quality Control and Defect Investigation Supervisor with Trans-Canada Air Lines, Winnipeg, is now Assistant to the Superintendent of Maintenance and Overhaul with the same Company.

Mr. William E. Marr, Associate Member, who for many years past has travelled extensively both at home and abroad for Barber-Colman, Limited, has now joined Dowding & Doll, Limited, London, as Technical Sales Representative for Cheshire, Lancashire and Yorkshire.

Mr. G. E. Rennard, Associate Member, has now been promoted to Works Manager at the Stanningley Works of George Cohen, Sons & Co., Limited.

Mr. G. W. Rhodes, Associate Member, has been appointed Lecturer in Mechanical Engineering in the Department of Mechanical Engineering at the County Technical College, Stafford.

Mr. R. S. Russell, Associate Member, has been appointed Senior Works Engineer with the Glasgow Corporation Transport Department.

Mr. B. J. Stedman, Associate Member, is now Sales Manager of The Metal Box Company of India, Limited, Bombay.

Mr. E. Jeacock, Associate, has left D. Napier & Son, Ltd., Liverpool, and is now Plant Engineer with The Garrard Engineering and Manufacturing Co., Ltd., Swindon, Wilts.

Mr. J. S. Allen, Graduate, is now a Senior Sales Engineer with The British Thermostat Co., Limited, Middlesex.

Mr. P. C. Bradshaw, Graduate, is now Assistant Works Director at Tilghman's Patent Sand Blast Co., Ltd., Manchester. Before taking up his new appointment, Mr. Bradshaw was Hon. Secretary of the Gloucester Section of the Institution.

Mr. F. Caldwell, Graduate, has recently taken up an appointment as Junior Materials Handling Engineer with F. Perkins, Limited, of Peterborough.

Mr. L. L. Chadderton, Graduate, has resigned his position as Draughtsman with Flexibox, Ltd., Manchester, and has taken a position as Mechanical Engineering Draughtsman with Andrews & Beaver, Limited, Christchurch, New Zealand.

Mr. G. R. Connor, Graduate, has relinquished his position with the English Steel Corporation, Manchester, and has taken up an appointment with Joseph Sankey & Sons, Limited, Wellington, as a trainee.

Mr. F. Cawood, Graduate, has now taken up a position as Designer Draughtsman in the Machine Tool Division of Fairbairn Rawson Combe Barbour, Limited, Leeds.

Mr. P. J. Galliford, Graduate, has left Handley Page, Ltd., and is now a Research Engineer with P.E.R.A., at Melton Mowbray, Leicester.

Mr. James A. Harris, Graduate, is now Chief Production Engineer with Vidor, Limited (Batteries), Dundee.

Mr. M. Naddell, Graduate, has recently taken up an appointment in Canada with John Inglis and Company, of Toronto, as a Class I Tool Designer.

Mr. J. E. Reeve, Graduate, was recently appointed Chief Designer and Development Engineer with G. Hopkins & Sons, Ltd., London.

Mr. A. W. Stannard, Graduate, was recently appointed Production Manager of Thomas Mercer, Ltd., St. Albans, which firm he joined on his return from Canada.

Mr. L. J. Upstone, Graduate, has now been demobilised from the Army, and has taken up an appointment with Civitas Industrial Development, Limited, Kingston, as Assistant Planning Engineer.

Mr. J. Walker, Graduate, has left the Ford Motor Company at Chicago, and has taken up an appointment with Lear Incorporated, Santa Monica, California, as a Designer.

BIRMINGHAM SECTION TOUR

The October issue of The Journal contained a reference to the Birmingham Section tour of Germany, with the statement that the trip was organised by Mr. Tom Houghton. The Editor has since been informed that the event was organised by the Graduate Social Secretary, Mr. A. C. Turner, and that while Mr. Turner was away on a business trip to Scandinavia, Mr. Houghton kindly handled the arrangements, for which the Section are very grateful.

JOURNAL BINDERS

Members are advised that binding cases for the Journal are available, and may be ordered from Head Office. The cases, which are strongly made and covered in dark red leather cloth, with "The Institution of Production Engineers Journal" in gilt on the spine, will each hold 12 copies of the Journal. The price per case is 10/-, post free.

Hazleton Memorial Library

REVIEWS & ABSTRACTS

Members are asked to note that the Library will normally be open between 10 a.m. and 5.30 p.m. from Monday to Friday each week. It would be helpful if, in addition to the title, the author's name and the classification number could be quoted when ordering books.

Members are reminded that the Library service is available to all members of the Institution and the Librarian is always willing to assist with enquiries.

REVIEWS

"**Manufacture and Properties of Steel Wire**" by Anton Pomp translated from the German by C. P. Bernhoeft. (Based on the 2nd German Edition, 1952), *London, Wire Industry Ltd.,* 1954. 358 *pages. Illustrations. Diagrams.*

This book will appeal mainly to those concerned with the research and production problems of wire in its many forms, and who should, as a result, be fully conversant with the types of equipment used.

The main landmarks in the development of wire drawing are dealt with briefly and concisely.

Under the headings "Fundamentals of Wire Drawing" and "Alteration of Properties of Material Through Wire Drawing" there is much of interest and value and, whilst everyone may not be in complete agreement with all the views expressed, they are presented in a manner which will, without doubt, make the reader reconsider his own views where they are not in accord with those of the Author.

The chapter dealing with lubrication, though brief, clearly outlines the basic requirements of lubrication; but the present rapid advancement by the incorporation of additives to lubricants as a method of increasing efficiency, is perhaps, not sufficiently stressed. It is also unfortunate that this chapter opens with illustrations and comments on the full lock section of a locked coil rope in relation to the formation of a so called "martensitic zone", this is highly controversial and many will not be in complete accord with the terminology and the suggested stage at which it occurs.

The chapters dealing with annealing, patenting, hardening and tempering are comprehensive and up to date, and summarise very ably the findings of many workers on this subject. There is much of interest, here, not only to the newcomer, but to the more experienced.

Galvanising is confined particularly to the more orthodox processes which are commercially available, but does not deal sufficiently with the metallurigical aspect of the matter, especially in connection with marine usage.

Wire testing covers the range of essential orthodox testing equipment quite adequately, but deals generally with tests which impose static, rather than dynamic loads.

The chapter covering drawing tools is compact but comprehensive and includes up to date methods of testing dies. The Author has however, failed to mention the latest methods of shaping carbide dies.

To summarise, the work is reasonably comprehensive and suitable for the more advanced reader.

J.B.

"**The Manufacture of Iron and Steel**" by D. J. O. Brandt. Published under the auspices of the British Iron and Steel Federation by English Universities Press Ltd. *London,* 1953. 348 *pages. Illustrations. Diagrams.* 15/-. (City and Guilds series.)

This book is primarily intended as a course text book for student operatives who intend to take the City and Guilds Iron and Steel Operatives Examination. The Author's preface also conveys the hope "that First and Second Year Students at Universities and Technical College may find the book useful as a background before they embark upon a more detailed and theoretical study of the physical, chemical and metallurgical bases of Iron and Steel Production".

The Author has had the assistance and full co-operation of the Iron and Steel Federation in compiling this authoritative book on the manufacture of iron and steel.

The book is divided into five sections:—The Ironmaking Industry; The Iron Founding Industry; The Steelmaking Industries; The Steel Finishing Processes; The Integration, Layout and Location of the British Steel Industry.

The manner in which the Author has combined the geography and pre-treatment of the ores, the historical and efficiency developments of the various iron and steel making processes, the metallurgical aspects and principles involved in the steel finishing processes—i.e. hot and cold rolling, cold drawing, forging and tube manufacture, also the lay-out of iron and steelworks, and the economic aspects relating to the location of the iron and steel industry makes this text book very interesting and informative reading.

It is recommended to the lecturer, student operator, administrator or anyone who wishes to acquire knowledge of the industry.

The Author has been mindful of the difficulties experienced by students regarding conflicting terms and their definitions. Chapter I entitled The Meaning(s) of the Terms "Iron and Steel", is devoted to explanations of the various terms given to iron and steel. Throughout the book considerable use has been made of the asterisk to denote terms or phrases which require explanation: such explanations are, usually, to be found at the bottom of the page: and although they are in the main adequate, the Author's definition of Ferrite is subject to query.

Commendable features are the short forewords at the beginning of each section and the three chapters devoted to recapitulation.

The book is well illustrated by diagrams and photographs which have been used effectively to emphasise the text.

Fine appendices—Steelwork Refactories; Pyrometry; Tensile, Hardness and Notched Bar Impact Testing; Alloy Steels and Heat Treatments; The City and Guilds Iron and Steel Operatives Examination, widen the scope of the book in relation to the City and Guilds syllabus. Intending examinees will appreciate the advice given in Appendix V.

The value of the publication would have been enhanced if questions had been attached to the end of each chapter.

There is no doubt that this textbook will fill the need for a modern authoritative book on the subject and is considered first class value. V.D. *and* R.D.O.

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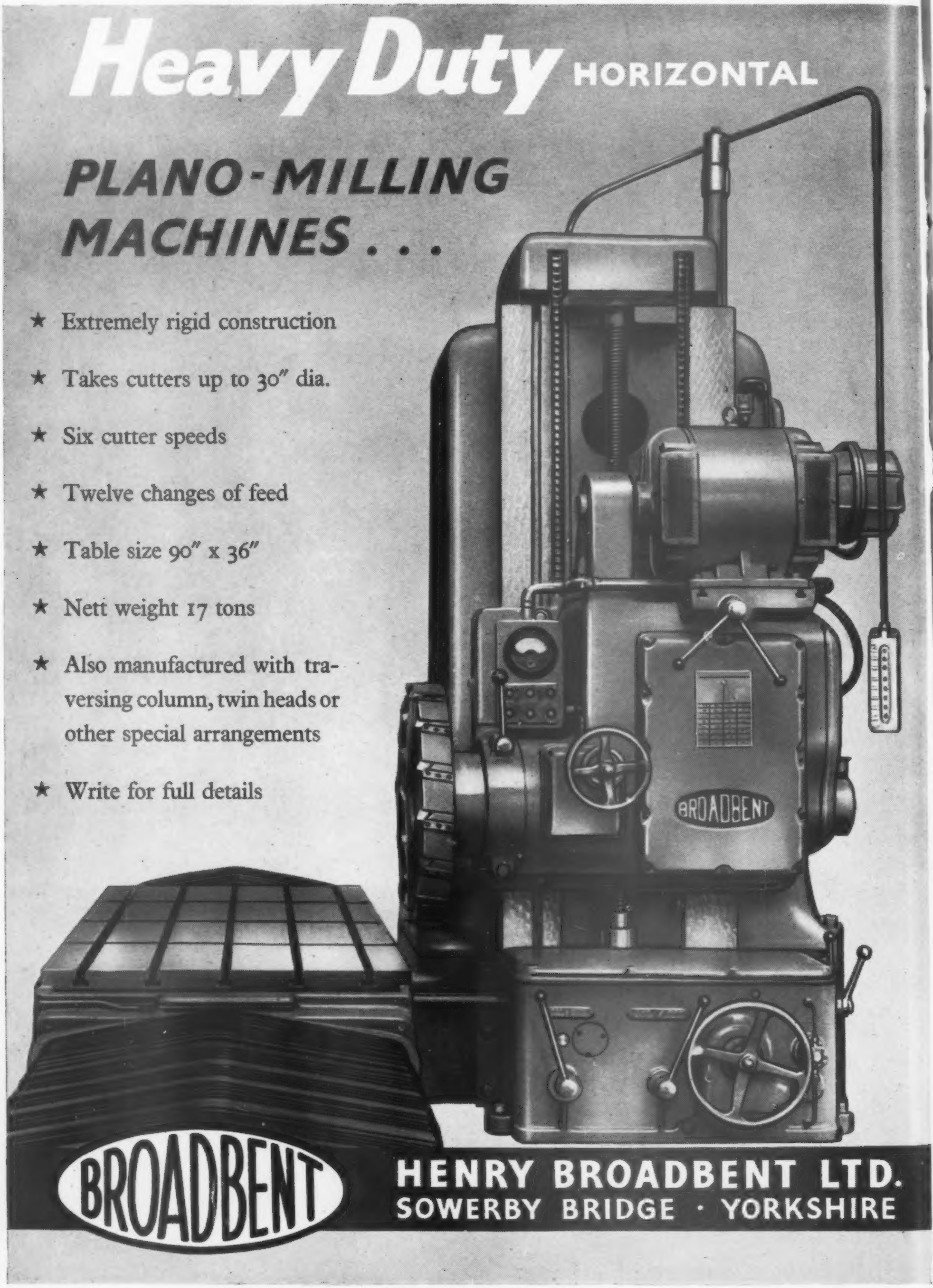

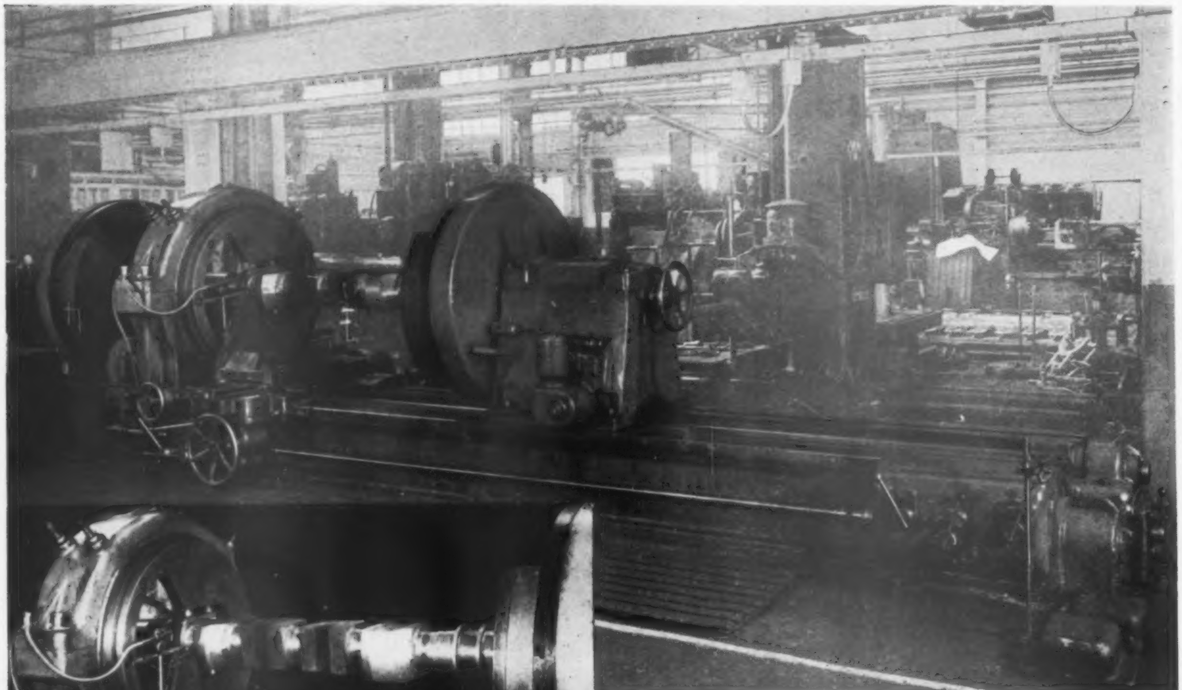

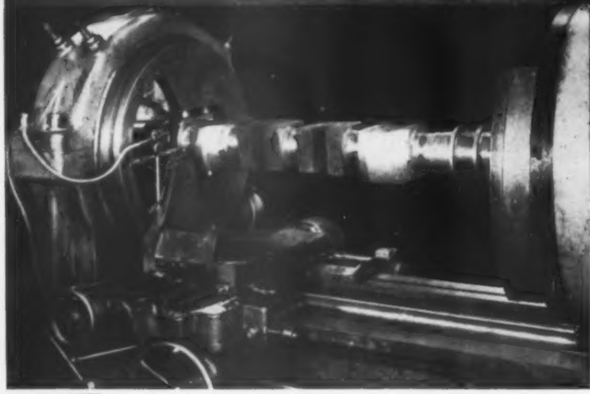

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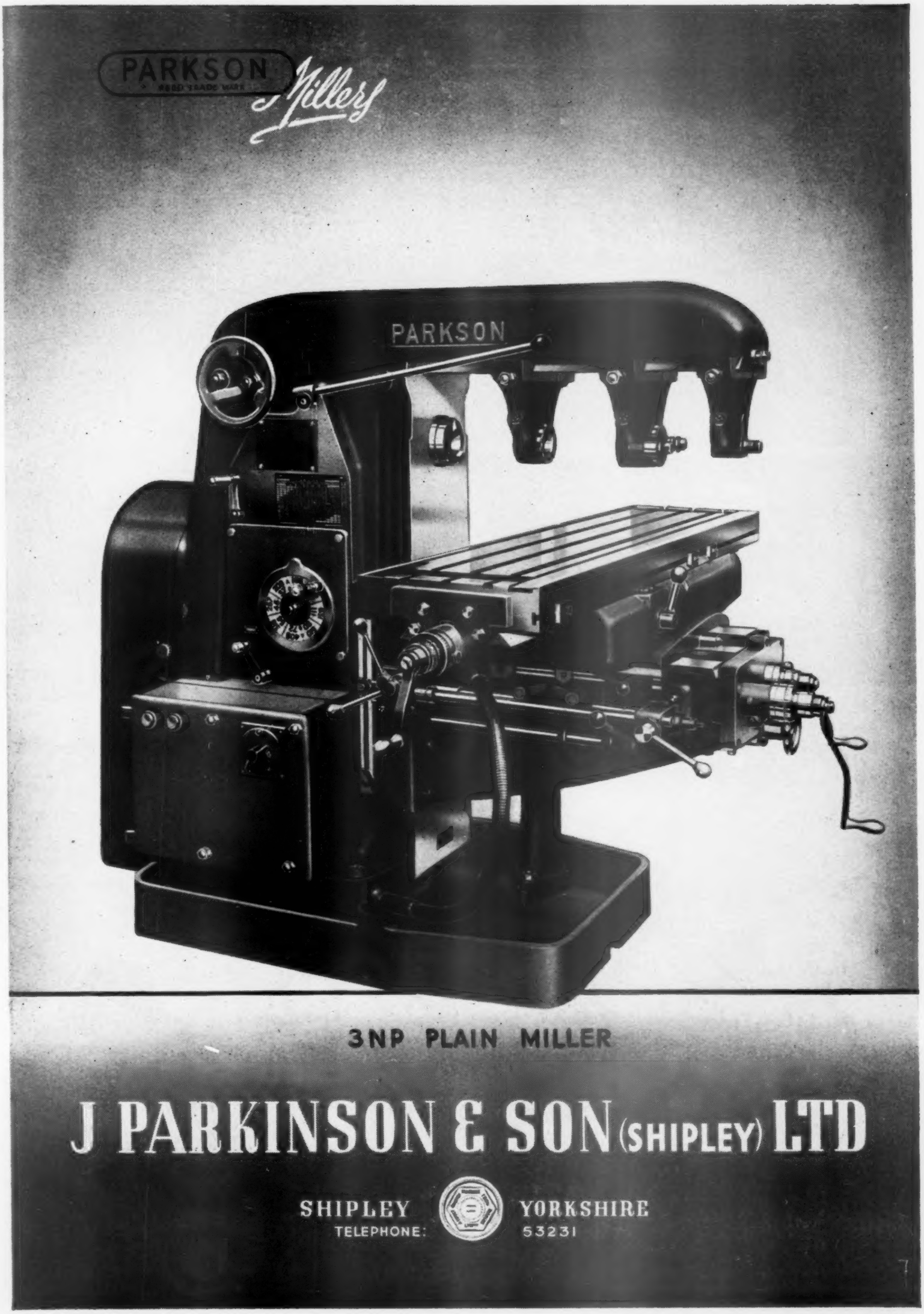
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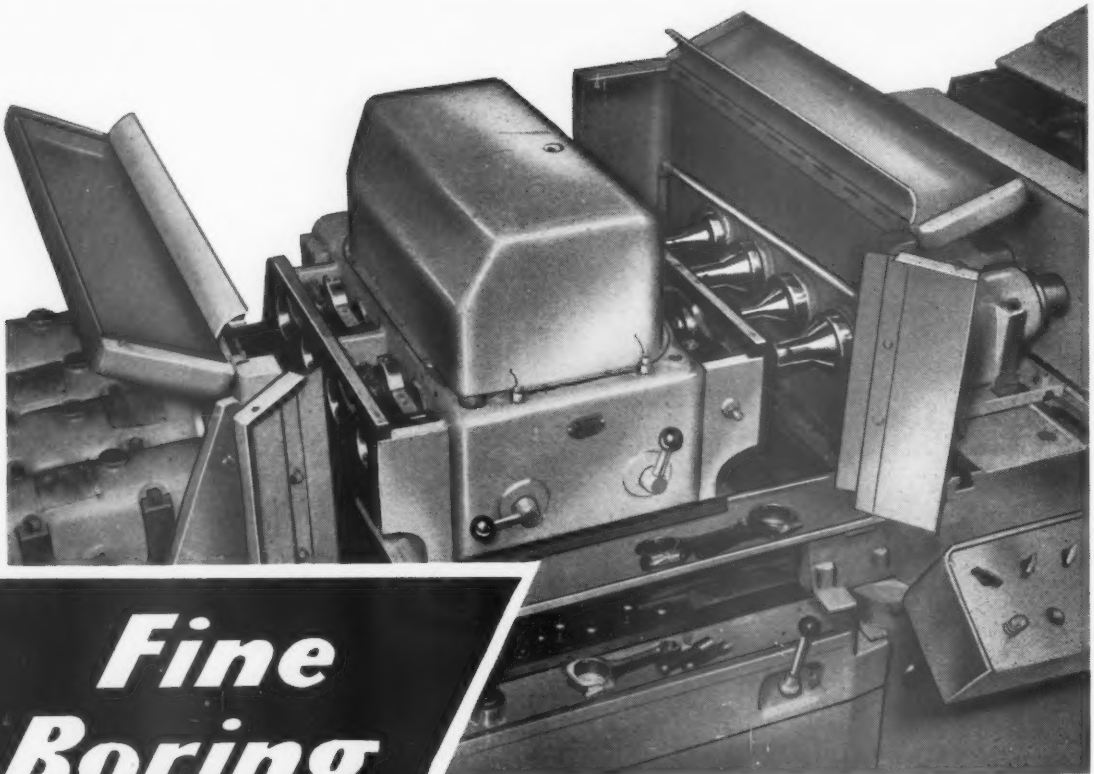

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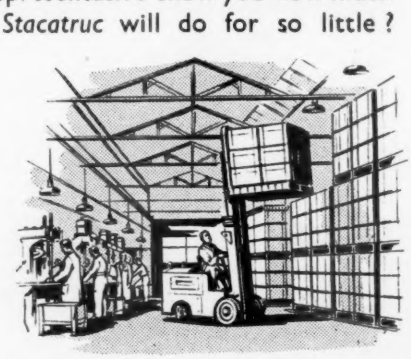

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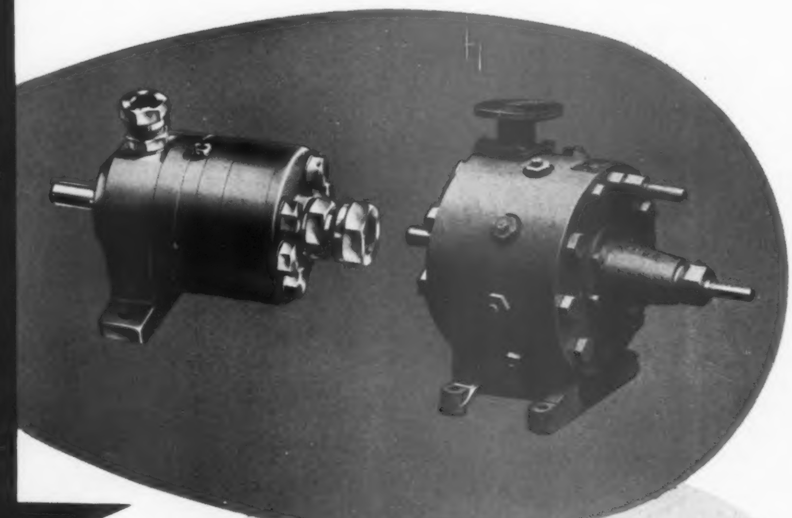

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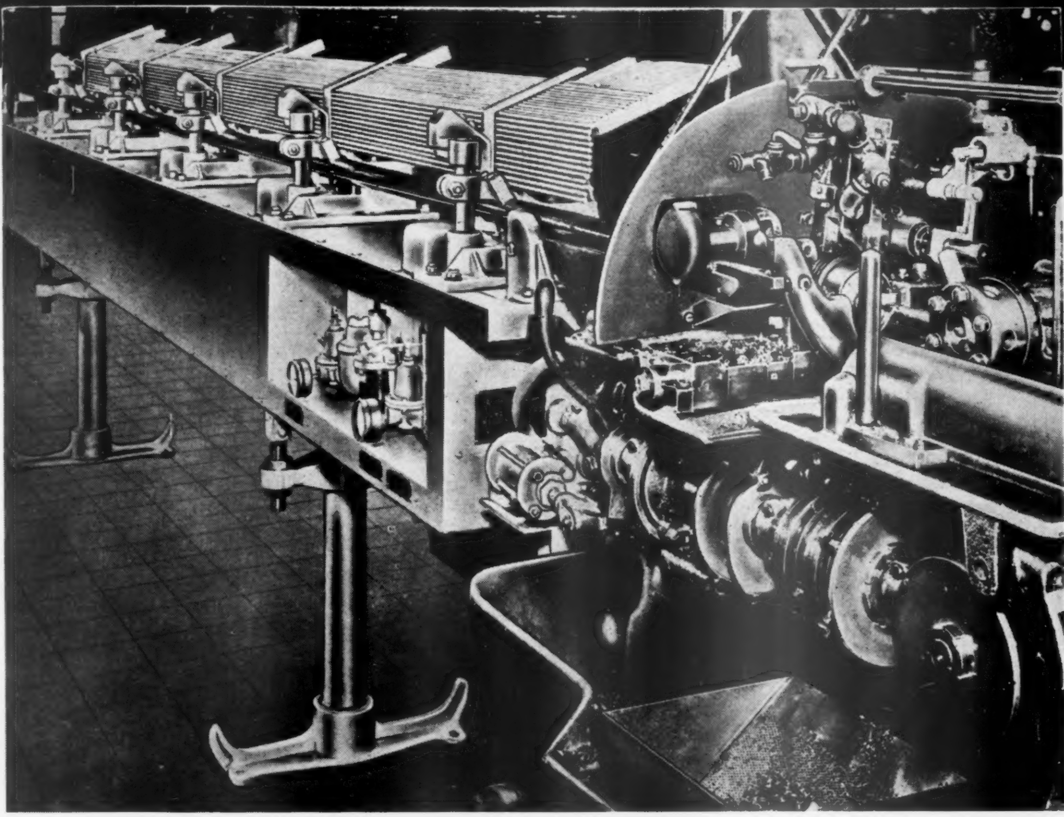

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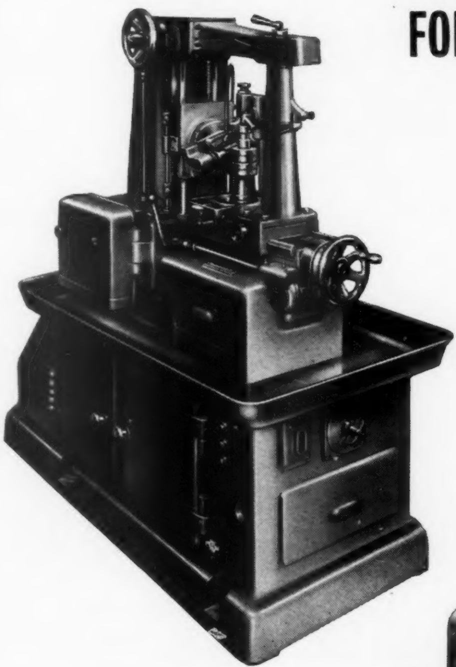

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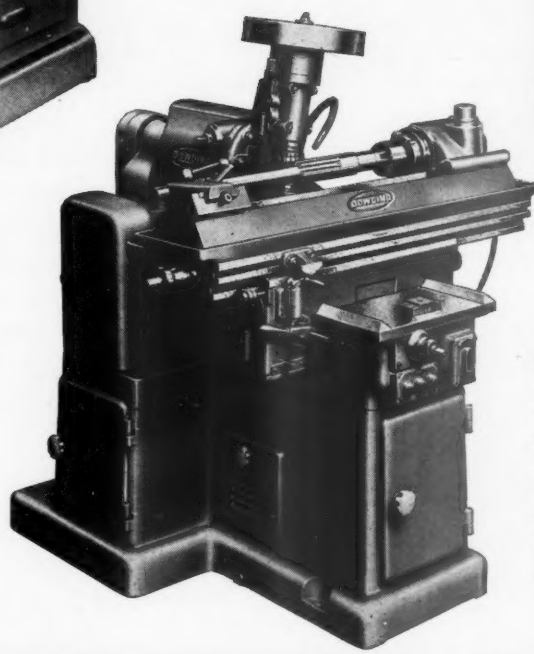

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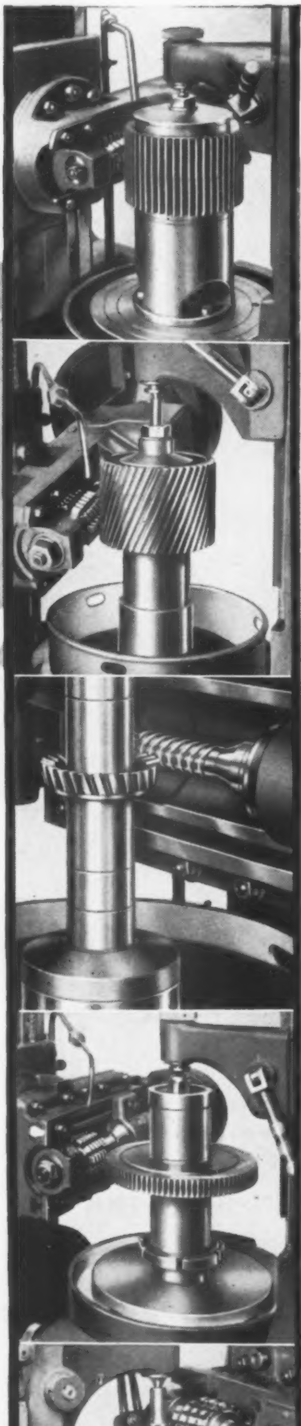

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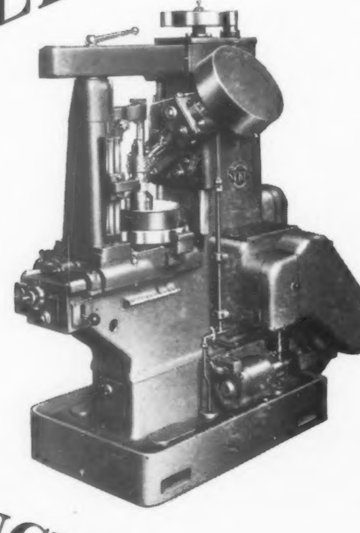

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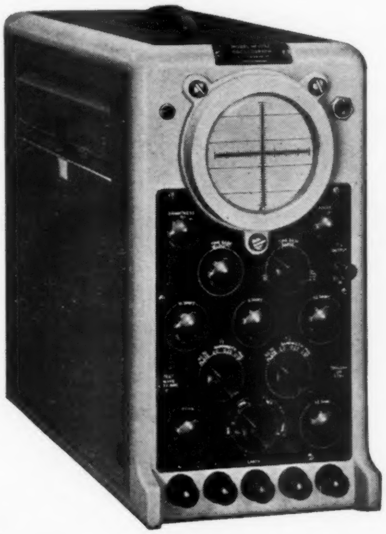

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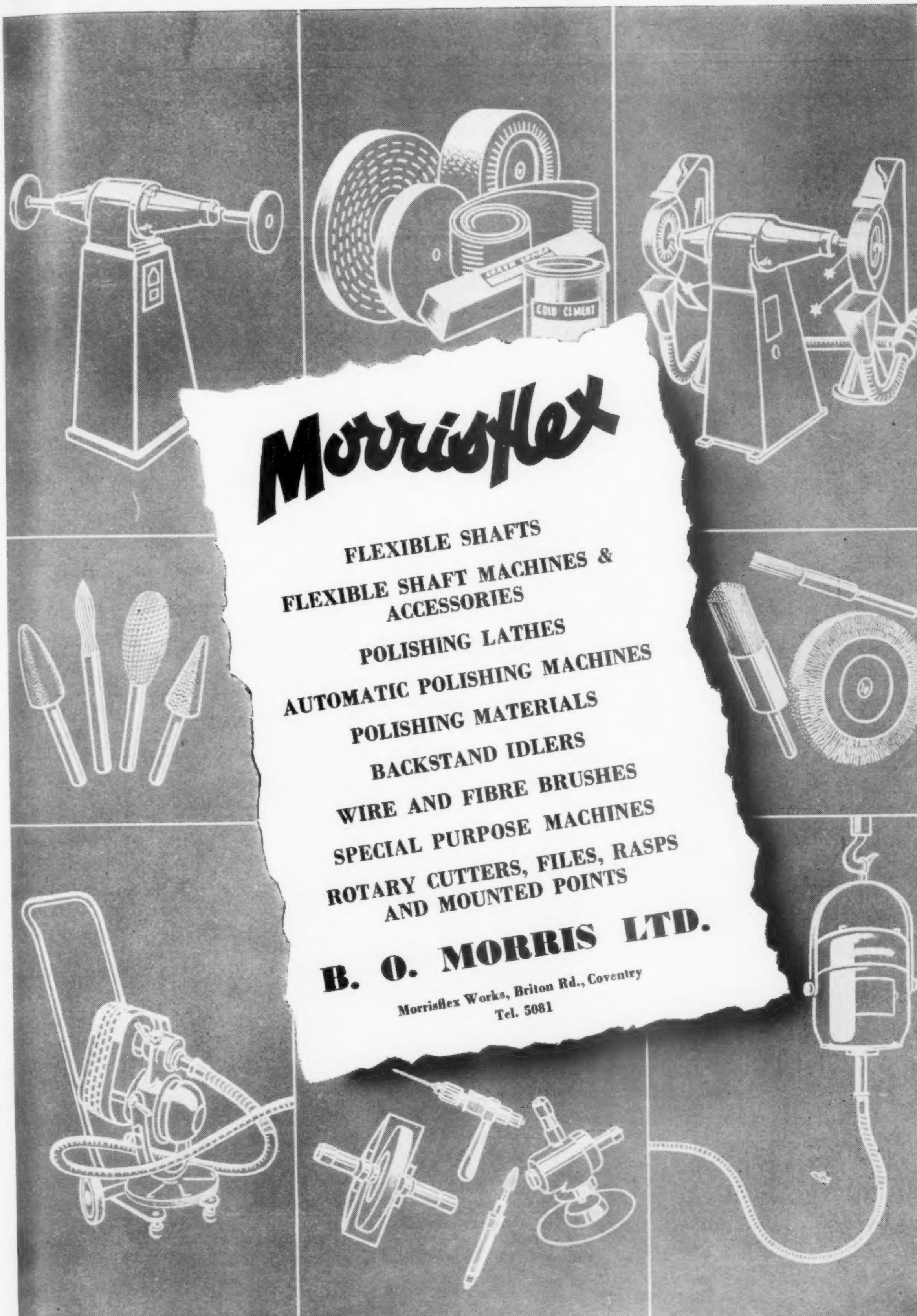

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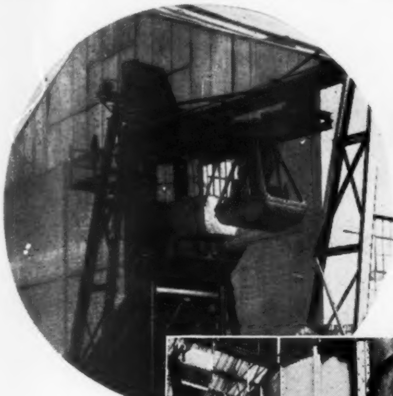

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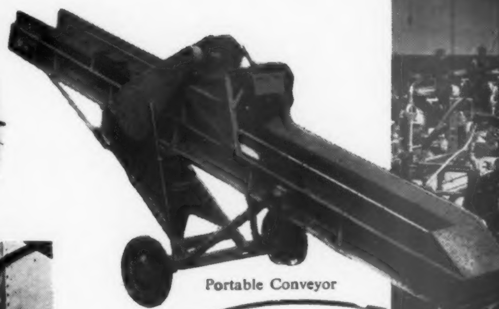

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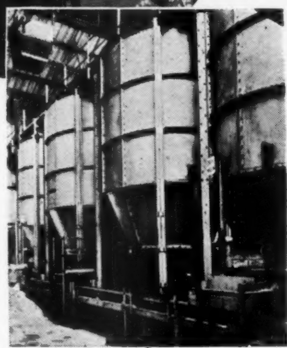

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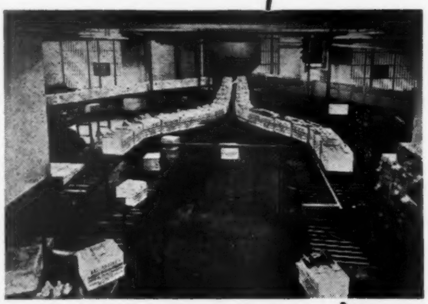

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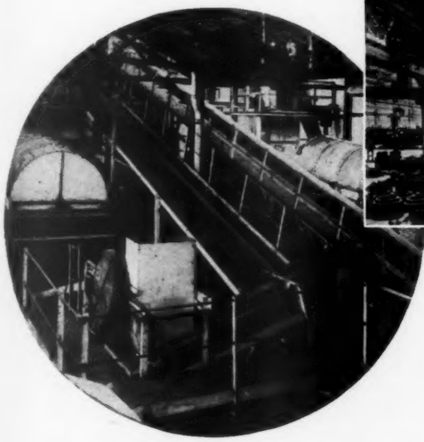

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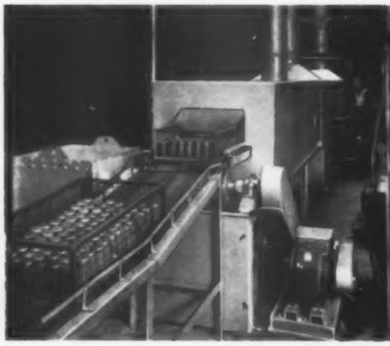

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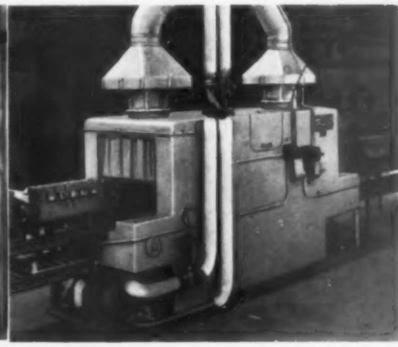

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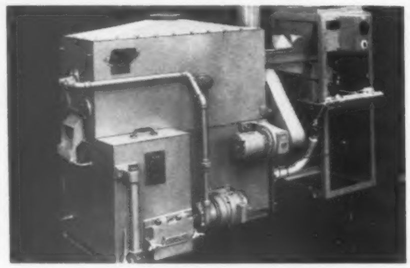

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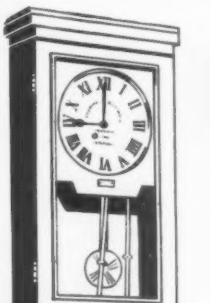
FOR TIME RECORDS AND COST CONTROL



GLEDHILL - BROOK

The Gledhill-Brook Company was intimately concerned with the earliest problems associated with the design and production of time recording machines. The first efficient electric-impulse recorders with accurate timekeeping independent of electric frequency or external influence were produced by Gledhill-Brook.

One of industry's urgent needs is the reduction of waste—especially the waste of time which costs money. That is where we are concerned and qualified to help. Our wide range of time-recording models covers most needs for the control of wages and labour.

THE J.M.C. MODEL

SPECIALLY DESIGNED FOR SMALL STAFFS

This is a recent GLEDHILL-BROOK product. It records attendance times IN and OUT and job process times ON and OFF. It prints on the face of the card and requires the card to be headed on one side only. Fitted with patent Gledhill-Brook electrical movement, or with mechanical movement if so desired.

STEEL CASE

CELLULOSE FINISH

GLEDHILL-BROOK TIME RECORDERS LIMITED

20, EMPIRE WORKS HUDDERSFIELD

"Give me room!"

GASPED THE PRODUCTION MANAGER

"I'm being choked", he said. "I'm producing the goods faster than ever, but what's the good? I've got to slow down to enable the stuff to be moved off the floor. I've carried on somehow, but this is the end. Come and look." We did.

His production machinery was tip-top, but oh!—his materials handling equipment was right out of the Ark! "For months now I've been nagging the Board to call in Yale", he moaned, "but they just wouldn't listen."

"Well, now we're here, let's get down to it", we said as gently as we could. He showed us what wanted moving—how far—and how often. Together we worked out a scheme that did all that and *increased his effective storage space more than 25%!*

Now he's producing to capacity, his handling costs are less than he had ever hoped and the Yale trucks are giving him the kind of trouble-free service he'd only dreamed about.

IS LACK OF SPACE RESTRICTING YOUR OUTPUT?

FORK LIFT *Lifts, moves and stacks over low-load floors: saves time, space and manpower wherever it's put to work.*

Yale's versatile

"WORKSAVER"

is specially suitable for smaller plants

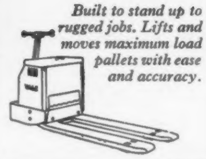
Among the wide range of Yale handling equipment the "Worksaver" series of trucks is of special interest to factories where restricted space or low-load floors have previously made mechanical handling impractical. Its small size, light weight and extreme ruggedness give big-truck advantages with small-truck economy and convenience.

It will lift, move and stack raw materials or finished products. It saves time, space and manpower. You can ride it or walk it. And it will start cutting costs from the minute you put it to work.

The "Worksaver" is available in five basic types: pallet, low lift platform, high lift platform, fork lift and tractor.

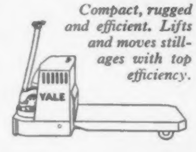
PALLET

Built to stand up to rugged jobs. Lifts and moves maximum load pallets with ease and accuracy.



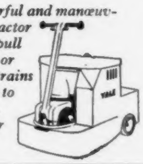
PLATFORM

Compact, rugged and efficient. Lifts and moves stillages with top efficiency.



TRACTOR

A powerful and manœuvrable tractor unit to pull trailers or trailer trains with up to 700 lbs. drawbar pull.



YOU GET ALL THESE ADVANTAGES WITH THE "WORKSAVER"

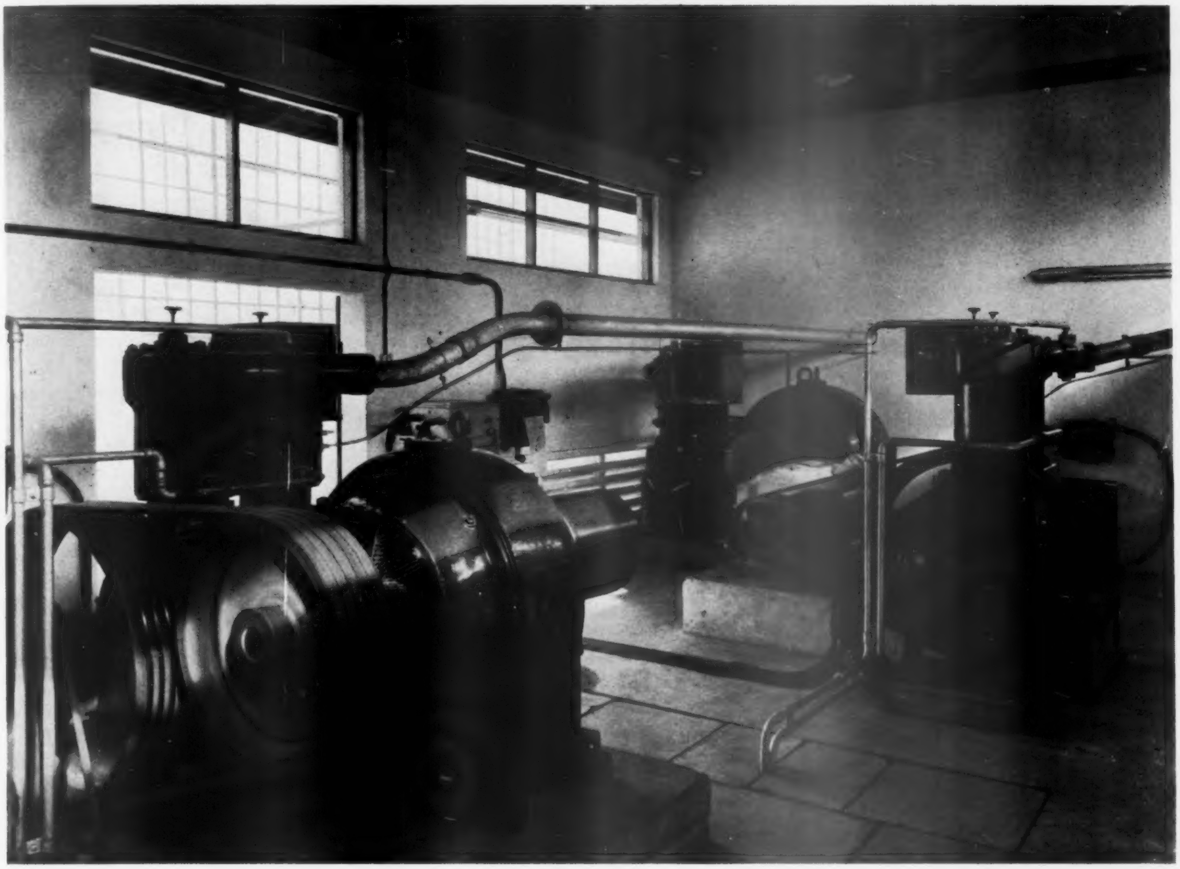
* *Manœuvrable in small spaces and narrow aisles.*
* *Light weight with great strength and power permit heavy duty work on low-load floors.*
* *Dead man control cuts power and applies brakes automatically in emergency.*
* *Simple fingertip controls—unskilled staff can move, lift and stack with speed and safety.*
* *Low initial cost, low running cost, economical maintenance, long life.*

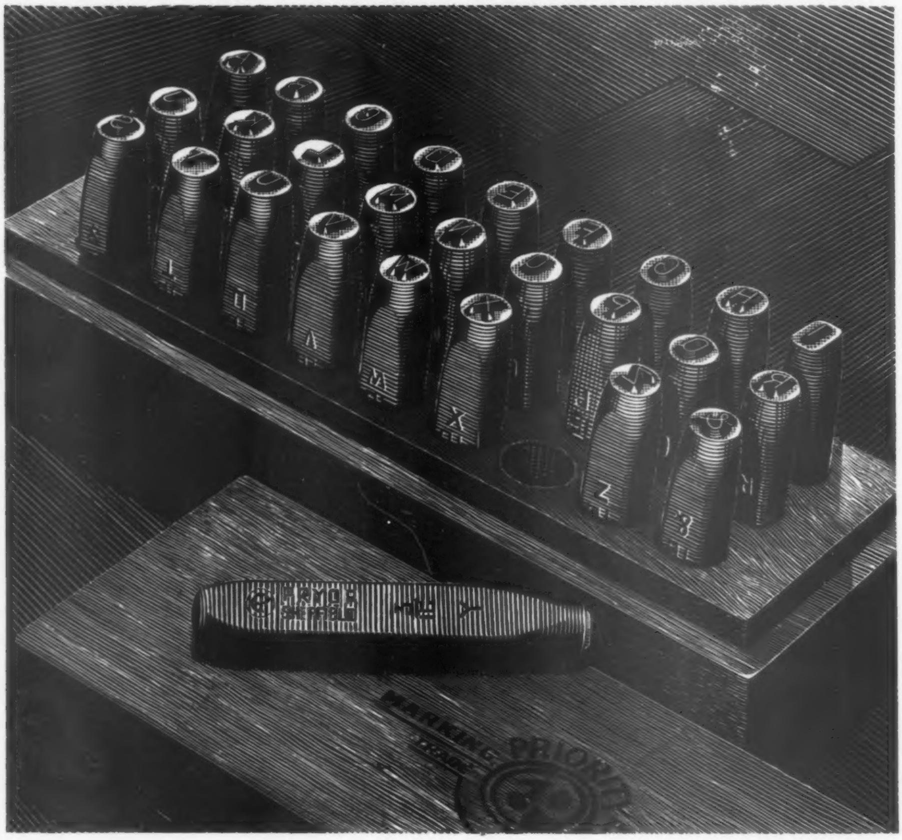
MATERIALS HANDLING EQUIPMENT

MADE IN ENGLAND BY **YALE**

REGISTERED TRADE MARK

THE YALE & TOWNE MANUFACTURING COMPANY, MATERIALS HANDLING DIVISION, DEPT. U.II, WEDNESFIELD, STAFFS. PHONE: WILLENHALL 630.





INDEX TO ADVERTISEMENTS

All communications regarding advertisements should be addressed to the Advertising Managers, T. G. Scott & Son, Ltd. Crown House, 143-147, Regent Street, London, W.1. Phone: Regent 3891.
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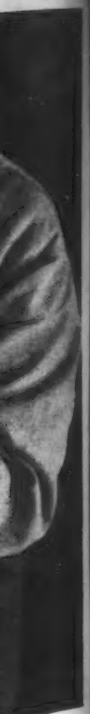

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Vol. 33, No. 11
NOVEMBER, 1954

JOURNAL SUPPLEMENT

INSTITUTION OF PRODUCTION ENGINEERS, 10, CHESTERFIELD ST., LONDON, W.1

THE 1954 VISCOUNT NUFFIELD PAPER

As announced in the Journal Supplement last month, the 1954 Viscount Nuffield Paper will be presented at the Royal Institution, London, **on 9th December next** at 6.30 p.m. The speaker will be **Major-General W. A. Lord, C.B., C.B.E., Director of Mechanical Engineering at the War Office,** who will take as his subject the vital importance of the application of modern production technology and management to the work of the Corps of Royal Electrical and Mechanical Engineers.

Admission to the meeting will be by ticket only, and as it is anticipated that many members will be interested in attending, early application for tickets and preprints is advised to ensure a seat in the lecture theatre. Tea will be served from 5.30

The application form for tickets and preprints appears overleaf.

LECTURES ON INDUSTRIAL LEADERSHIP

A series of five lectures on "New Developments in Industrial Leadership", designed for directors and senior executives, has been arranged by the Department of Management Studies, The Polytechnic, Regent Street, W.1., and will take place on 5th, 12th, 19th, 26th November, and 3rd December, 1954.

The purpose of the lectures is to provide directors and senior executives with opportunities to compare the latest trends in four countries which are making distinctive contributions to industrial leadership. It is emphasised that it is not the intention of these lectures to describe developments abroad in order to urge their adoption at home. It is thought, however, that at a time when managerial leadership in large and small industries is adapting itself to many complex situations, executives in Britain will wish to study developments in competitive countries.

The lecturers and subjects are:

Dr. J. A. C. Brown—"Surveying the British Scene".

Mr. Jerome F. Scott—"New Concepts of Leadership and Management in U.S.A.".

Mr. Frank A. Heller—"New Developments in Industrial Democracy in Germany".

Mr. H. Hauck—"Modern Management in Private and Nationalised Industry in France".

The fifth meeting will be a discussion forum attended by the four speakers. The Chairman for the first three meetings will be Sir Walter Puckey, and for the last two, Sir Geoffrey Vickers.

A brochure and form of application can be obtained from the Registrar, Department of Management Studies, St. Katharine's House, 194, Albany Street, N.W.1.

MEETINGS

Visitors tickets may be obtained from Section Honorary Secretaries

NOVEMBER 1954

BIRMINGHAM 7 p.m. NOVEMBER 17th
The James Watt Memorial Institute, Great Charles Street, Birmingham.
"The Production and Properties of Titanium and Titanium Alloys" by R. L. P. Berry, Ph.D., M.Sc.

COVENTRY 7 p.m. NOVEMBER 16th
The Craven Arms, High Street, Coventry.
"The Design of Transfer Machines under Application to Production" by H. W. Holbeche and F. Griffiths.

COVENTRY GRADUATE 7.30 p.m. NOVEMBER 9th
The Craven Arms, High Street, Coventry.
"Should Production Control Design?"—with special reference to automobile engineering. Debate. Joint meeting with the Institution of Mechanical Engineers.

To: The Secretary,
The Institution of Production Engineers,
10, Chesterfield Street,
London, W.1.

THE 1954 VISCOUNT NUFFIELD PAPER

to be presented at the Royal Institution, Albemarle Street, London, W.1. on Thursday, 9th December, 1954, at 6.30 p.m. (Tea from 5.30 p.m.)

I intend to be present at the above meeting. Please send me an admission ticket and preprint.

NAME..

ADDRESS..

PLEASE NOTE

No acknowledgment of this order will be made. Tickets and preprints will be distributed as soon as they are available.

CORNWALL **7.15 p.m. NOVEMBER 18th**
The Cornwall Technical College, Trevenson, Pool, Redruth. Local Discussion on "What subjects should be studied in Production Engineering Training?". Discussion Groups from local industries will be attending.

DERBY **7 p.m. NOVEMBER 15th**
College of Art, Green Lane, Derby.
"Mechanical Accountancy", by E. Carden. There will also be a film, "Figures at Work".

DONCASTER **7 p.m. NOVEMBER 9th**
The Danum Hotel, Doncaster.
"Motion Economy" by Miss A. G. Shaw, M.A., M.I.Prod.E.

EASTERN COUNTIES **7.30 p.m. NOVEMBER 12th**
The Diocesan Hall, Tower Street, Ipswich.
"The Measurement and Significance of Surface Finish" by R. E. Reason, A.R.C.S.

GLASGOW **7.30 p.m. NOVEMBER 4th**
The Institute of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2.
Open Discussion Night. "The Problem of Deburring" led by W. P. Kirkwood, B.Sc., M.I.Mech.E., M.I.Prod.E.

GLASGOW **7.30 p.m. NOVEMBER 18th**
The Institute of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2.
"The Basic Nomenclature of Cutting Tools" by G. V. Stabler, B.Sc., M.I.Prod.E., M.I.Mech.E., M.I.E.E.

GLOUCESTER & DISTRICT
7.15 p.m. NOVEMBER 4th
The Bell Hotel, Gloucester.
"Productivity" by J. L. Daniels. Joint meeting with the Western Section of the Plastics Institute.

HALIFAX **7.15 p.m. NOVEMBER 2nd**
The White Swan Hotel, Halifax.
"The Shell Moulding Process" by D. N. Buttrey, M.Sc., A.R.I.C., A.P.I.

HALIFAX GRADUATE **7.30 p.m. NOVEMBER 8th**
The Whiteleys Cafe, Westgate, Huddersfield.
"The Construction and Development of Artificial Satellites" by M. S. Wright (Yorkshire Secretary, British Interplanetary Society).

LEICESTER **7 p.m. NOVEMBER 11th**
The Balmoral Room, Bell Hotel, Leicester.
"Production Milling" by A. R. Hambidge.

LEICESTER **7 p.m. NOVEMBER 25th**
The Balmoral Room, Bell Hotel, Leicester.
Section Dinner.

LIVERPOOL GRADUATE **9 a.m. NOVEMBER 13th**
Works visit to Messrs. C. Tinling & Co. Ltd., Prescot, Nr. Liverpool.

LONDON **7 p.m. NOVEMBER 11th**
The Royal Empire Society, Northumberland Avenue, (Craven Street Entrance) London, W.C.2.
"The Measurement of Surface Finish" by S. F. Smith. Joint meeting with the Institute of Metal Finishing.

LONDON **7 p.m. NOVEMBER 25th**
Powers-Samas Accounting Machines Ltd., Aurelia Road, Croydon, Surrey.
"Barrel Finishing" by H. D. Goulding, B.Sc.(Eng.)A.C.G.I., A.M.I.Mech.E.

LONDON GRADUATE **7.15 p.m. NOVEMBER 17th**
The Institution of Production Engineers, 10, Chesterfield Street, London, W.1.
"Use of Mechanical and Electronic Equipment for Production Planning and Control" by E. Carden.

LONDON GRADUATE **9.15 a.m. NOVEMBER 13th**
A Works Visit to The British Oxygen Co. Ltd., Cricklewood, North Circular Road, London, N.W.2.
Comprehensive demonstration of all types of gas welding, supplemented by films.

LUTON **7.15 p.m. NOVEMBER 30th**
The Pink Room, W. H. Allen, Sons & Co. Ltd., Bedford.
"Noise and Vibration in Machinery" by Dr. A. J. King, M.Sc.(Tech), M.I.E.E., F.Inst.P.

LUTON GRADUATE **7.45 p.m. NOVEMBER 22nd**
The Lecture Hall, Central Library, George Street, Luton. Graduate Evening—Graduates' Papers will be read followed by questions put to a Production Panel of Senior Section members.

MANCHESTER **7.15 p.m. NOVEMBER 15th**
Reynolds Hall, (Room C.3), College of Technology, Sackville Street, Manchester, 1.
"The Practical Application of Production Engineering Research" by Dr. D. F. Galloway, Wh.Sch., B.Sc.,(Hons), M.I.Mech.E., M.I.Prod.E.

MANCHESTER GRADUATE
7.15 p.m. NOVEMBER 2nd
Reynolds Hall, (Room C.3), College of Technology, Sackville Street, Manchester, 1.
"Recent Advances in Plastics, Polytetrafluorethylene" by E. M. Elliot, A.M.I.Prod.E.

applicant's abilities. The company operates a superannuation plan and can sponser assisted immigration for the appointee and his family. Housing arrangements can be made on a lease or long term purchase basis. In view of the company's prominent national position and its expansion programme it is essential that applicants should at present hold a senior position in this field. Apply in writing in first instance to: Box No. 925, I.Prod.E., 10, Chesterfield Street, London, W.1.

Assistant Manager. The British Institute of Management requires an Assistant Manager for the Production Division of the Information Research Department. Applicants should have corporate membership of a suitable professional institution and some years' practical experience in production management in the engineering, textile or process industries. Work Study experience is essential and a knowledge of mathematical statistics an advantage. Good personality and the ability to write lucid English are required. Age 26-35. Salary according to qualifications and experience. Superannuation scheme. Applications in writing to: The Director, B.I.M., 8, Hill Street, London, W.1., marking envelope " AMP ".

Machine Tool Designer-Draughtsman required for the design of special purpose machine tools for the manufacture of specialised engineering products. Applicants should have obtained Higher National Certificate in Mechanical Engineering or equivalent standard and should have a knowledge of modern metal cutting methods, hydraulic operating and control mechanisms as applied to machine tools and gearing. A knowledge of electronic control is desirable. Must be capable of initiating and carrying out the complete project. Applicants should state age, details of training and subsequent posts held (in confidence), and salary required to: Box No. 926, I.Prod.E., 10, Chesterfield Street, London, W.1.

Experienced Work Study Engineer required for large manufacturing company in West London. Light engineering background preferred. Apply giving full details of experience, age, salary range, etc., to: Box No. 927, I.Prod.E., 10, Chesterfield Street, London, W.1.

Chief Work Study Engineer required to control the Time and Study sections at the Alperton Factory of the Glacier Metal Company Limited. Considerable scope available. Attractive salary for man with experience and high level of ability. Must be Corporate member of professional Institution and have served an apprenticeship. Apply in writing to: the Personnel Manager.

Engineering Staff. The Projectile and Engineering Co. Ltd., Acre Street, Battersea, S.W. are shortly opening a new Work Study department and require the following personnel:-

Methods Study Engineers, for medium and heavy machining.

Methods Study Engineers for medium to heavy press work and fabricated assemblies.

Materials Handling and Storage Engineers.

It is essential that applicants should have previous experience in the category for which they apply. The age desired is not more than 35 and technical qualification necessary is O.N.C. certificate as minimum. The positions are progressive and pensionable. An application form for completion will be sent on request.

Methods and Manufacturing Engineers. Developments in manufacturing techniques and product design which will appeal to production and mechanical engineers are proceeding at The English Electric Co. Ltd., Stafford. Vacancies will shortly occur in the following departments for engineers interested in manufacturing methods and product development: Heavy Electric Machines, Transformers; Rectifier; Switchgear; Instrument, Meter and Relay. Applications are invited from engineers either with experience of, or interested in this type of work. Previous direct experience is not necessary but a sound background of practical engineering in a manufacturing industry is essential, together with technical qualifications to at least O.N.C. level. Please write quoting Ref: 1225C., to: Dept. C.P.S. 336/7, **Strand, W.C.2.**

Planning Engineer required by the Telephone Manufacturing Company Limited, Martell Road, West Dulwich, S.E.21, with experience of pre-production planning of light electro-mechanical components. Applicants should have reached H.N.C. standards and possess a sound knowledge of production methods. Staff pension and bonus schemes after qualifying period. Five day week. Apply in writing to: Personnel Department.

Top-Level Production Executive of exceptional experience and calibre is required by a progressive group of companies in the light engineering field, accepted as one of the most advanced in its production methods in Britain today. The post demands professional engineering qualifications, practical experience of current production techniques, and administrative ability above the average. The proposed appointment will entail complete responsibility for one of the Group's manufacturing units employing up to 2,000 people. Recent experience in the instrument or electronic industry would be an advantage. A salary will be offered commensurate with ability up to £5,000 per annum. Production executives who consider their engineering and administrative qualifications equal to this important appointment are invited to write in strict confidence (and with the assurance of careful consideration at the highest level) to: Box No. 928, I.Prod.E., 10, Chesterfield Street, London, W.1.

Chief Estimator required for engineering firm in West Midlands manufacturing medium/heavy equipment. Applicants must have had a wide experience in a similar capacity and be fully qualified engineers. Good salary and superannuation scheme. State full particulars of experience and qualifications to: Box No. 929, I.Prod.E., 10, Chesterfield Street, London, W.1.

Tool Designer Draughtsman with experience in press tools jigs and fixtures for typewriter or similar product. Write stating experience and salary required—Tool Engineer, Byron Business Machines, Arnold Road, Nottingham.

Planning Engineer experienced in processing and machine loading for typewriter or similar product. Write stating experience and salary required—Tool Engineer, Byron Business Machines, Arnold Road, Nottingham.

Chief of Progress with knowledge of machine loading and progressing jobs throughout required for large light engineering shop. 5-day week. Good salary to right man. Apply: Sterling Engineering Co. Ltd., Rainham Road South, Dagenham, Essex.

Time Study Engineers required for engineering company, covering the manufacture of electrical and mechanical components. Sound knowledge of machine shop practice and modern methods necessary. Good salary to right men. 5-day week. Staff canteen facilities. Apply: Sterling Engineering Co. Ltd., Rainham Road South, Dagenham, Essex.

First Class Machine Tool Designers and Detailers required for work on special purpose machine tools for automobile and kindred trades. Applications will be treated confidentially. Staff pension scheme in operation. Write furnishing details of experience to: C.V.A. Jigs, Moulds & Tools Limited (No. 1 Factory), Hove, Sussex.

Production Manager required for service in a British territory overseas by old-established and progressive food manufacturing Company with a number of Branches. Specialised knowledge of the industry is not necessary, as experienced technical staff will be immediately subordinate, but proved management ability and mature outlook are essential. Age limits 30-45. Married man preferred. Substantial salary; accommodation at nominal charge; contributory medical insurance scheme covering employee and family; home leave; free passages. Replies will be treated in strict confidence. Box No. 930, I.Prod.E., 10, Chesterfield Street, London, W.1.

Assistant to Plant Engineer required with knowledge of factory layout and all services. Drawing office experience required and a thorough mechanical engineering back-

ground. Pension scheme and staff bonus after qualifying period. Apply: Personnel Dept., Telephone Manufacturing Co. Ltd., Martell Road, West Dulwich, London, S.E.21. Tel: GIPsy Hill 2211.

Tool Estimator required by a large Company in S.E. London district engaged in the telecommunications industry. Applicants must possess a good all round experience of toolmaking, including bakelite moulds. The position offers scope to the right type of man. Pension and staff bonus schemes after qualifying period. Write fully, stating age, experience and salary required to: Box No. 931, I.Prod.E., 10, Chesterfield Street, London, W.1.

Production Engineer required by Metal Cap and Box Manufacturer in the Barking district. Applicants must have had extensive tool making experience in this class of work, and be able to take charge of the Tool Room. Commencing salary £900 per annum. Apply in confidence, stating age and fullest details of experience to: The Managing Director, S.C. Lomax Limited, Barking-By-Pass Road, Essex.

Production Planner. Applicants are invited for a senior appointment entailing responsibility in a modern system of Production Control at a light/medium engineering works employing approximately 1,500 people. Applicants should have served an apprenticeship in general engineering and have a wide experience of batch and line production. This will be an executive position qualifying for participation in the Company's staff pension scheme. Write giving full details of experience, age, salary required and when available to: Box No. 932, I.Prod.E., 10, Chesterfield Street, London, W.1

Production Engineer required as assistant to the Manager by medium size engineering company. Applicant should have knowledge of quantity production methods, job layout and estimating, have had practical experience and the capacity to control mixed labour. Good prospects and excellent salary for man with initiative and willing to accept responsibility. Age up to 35. Write to: Erma Limited, Hong Kong Works, Exhibition Grounds, Wembley, Middlesex.

Time and Motion Study Engineer required by Hoover Limited, at their headquarters factory at Perivale, Middlesex. Minimum age 25. Applicants should be experienced in skill and effort rating by elements and work study in light engineering. Starting salary will be in the region of £12 5s. 0d. per week to start. Write giving details of age, qualifications and experience, to: the Employment Officer, Hoover Limited, Perivale, Middlesex.

Methods Engineer and Ratefixers (2) required for factory on light/medium production. **Methods Engineer:** The essential qualification of person selected for this post should be previous experience in a similar capacity and the versatility to tackle both machine and assembly processes. In addition to this he must be able to calculate production times from component drawings. **Ratefixers (2):** These men will be primarily concerned with fixing of times on comparatively small batches and dealing with the problems that arise on the shop floor from day to day because most dealing will be direct with operators. Tact will be essential. Age, qualifications and salary required should be sent to: the Personnel Superintendent, K & L Steelfounders and Engineers Limited, Letchworth.

Time Study Engineer required by light electrical engineering firm, situated in London, N.17., to act as assistant in small department. Applicants must be at least of O.N.C. standard, fully experienced in speed and effort rating, work study and synthetic procedures as applied to machine and assembly departments. Please give full details of career to date in chronological order, together with age and salary required to: Box No. 933, I.Prod.E., 10, Chesterfield Street, London, W.1.

Design Draughtsman (Senior) with machine tool design experience required for new project and further development. Good mathematics and shop experience. Permanent position offering scope for advancement. Apply in writing giving age, training, experience, and qualifications to: Deakin Gears Limited, 201, Victoria Street, London, S.W.1.

Experienced Jig and Tool Draughtsman required by large lock manufacturers. H.N. Certificate in Production Engineering desirable. Some experience in press tools essential. Age not less than 25. Apply in writing giving details of experience to: Josiah Parkes & Sons Limited, Union Works, Willenhall, Staffs.

Draughtsmen. Hordern, Mason & Edwards Limited, have vacancies for senior men on power press design. Technical education preferable to H.N.C. level and shop experience necessary. Apply in first instance by letter to: Woodlands Farm Road, Birmingham, 24.

S. Smith & Sons (England) Ltd., the manufacturers of the largest range of instruments in the world are anxious to make the following additional appointments in their Motor Accessory Division:- **Time Study Engineers.** Preferably men with either machine shop or assembly flow line experience in light engineering. **Designer-Draughtsmen.** For work on prototype instrumentation projects. Men with experience of this or similar work and adaptable minds will be given preference. **Technical Assistant.** For department concerned with the supervision of products (instruments) to ensure that established standards are maintained. Applicants should not be less than 25 years of age. Minimum qualification: O.N.C. (Mechanical or Electrical). All these vacancies are at the Cricklewood Works, N.W.2., and offer salaries commensurate with the responsibilities of the job, and with prospects for advancement. Fullest details in chronological order should be sent to: the Personnel Manager, quoting reference MAI/PLI/63.

A Company in S.W. London manufacturing light sheet metal work have vacancies for the following staff:- **Chief Work Study Engineer:** A shop training is essential and previous work study experience in this type of work would be an advantage. **Production Draughtsman:** **To take** control of a small drawing office. Previous experience in the design of light sheet metal work and assemblies is necessary. **Planning Engineer:** Experience in the preparation of process layouts and tooling for power presses, press brakes, guillotines, capstan and centre lathe is essential. Write stating age, experience and qualifications to: Box No. 934, I.Prod.E., 10, Chesterfield Street, London, W.1.

Process Planning Engineers. Applications are invited for Process Planning Engineers for a new project in one of the factories of a well-known Midlands Group. The persons concerned should preferably be of National Certificate standard and must have had considerable experience in deep drawing press work, and subsequent finish machining operations. The factory is a new one with all modern amenities, within easy reach of Birmingham, Wolverhampton and Walsall. Applications in the strictest confidence should be forwarded to: Box No. 935, I.Prod.E., 10, Chesterfield, Street, London, W.1.

Planning and Production Control Manager: degree in chemistry and knowledge of reel coating essential. Mechanical engineering experience desirable. Age under 40. Accommodation found. Good salary and prospects. Details in confidence to: Box 936, I.Prod.E., 10, Chesterfield Street, London, W.1.

Production Engineer (on contract). Department of Commerce and Industries, Pretoria, South Africa, invite applications from qualified candidates for appointment to the above post on the establishment of the Board of Trade and Industries, Department of Commerce and Industries, Pretoria. The appointment will be on a contract basis for a period of five years with salary between £1,560 and £1,920 per annum, plus cost of living allowance at such rates as may from time to time be payable. The actual rate of remuneration will be determined in the light of the qualifications and experience of the candidate selected for appointment. Candidates must be in possession of an academic degree in industrial engineering, with training and practical experience in factory organisation, production planning and control, personnel policies and procedures and the application of management and costing principles. The successful applicant will be required to submit satisfactory

certificates of birth and health. Original certificates and testimonials should not be submitted in the first instance. Application must be made on the prescribed form (Z.83) which is obtainable from the Staff Clerk, Room 102, South Africa House, Trafalgar Square, London, W.C.2, to whom completed applications must be addressed not later than the 30th November, 1954. Full particulars of acadmeic qualifications and previous experience must accompany applications.

Managerial Post. A very interesting managerial post in a well-established Company will shortly be available to an executive of proved ability. The successful candidate will be required to build up a new product and to promote its application throughout industry. For this the selected applicant must possess (preferably in light engineering) a background of factory management with sound production experience and an appreciation of the commercial aspects of modern business. This important appointment will carry a four figure salary and participation in the Company's pension scheme. Reply to: Box No. 937, quoting BM.7, I.Prod.E., 10, Chesterfield Street, London, W.1.

Production Superintendent, required for factory situated in Nottingham. Must be experienced in aircraft sub-assemblies, good disciplinarian and have a knowledge of modern production systems. Please state full particulars to: Box No. 938, I.Prod.E., 10, Chesterfield Street, London, W.1.

Engineer. An unusual opportunity of a really interesting nature with housing assistance if needed. An Engineer required immediately for special assignments. Duties will entail cost reduction of products following investigation of function, design, purchasing and production. Progressive company in pleasant country district one hour west of London, making wide range of products using mechanical, electrical and hydraulic mechanisms. Applicants must have initiative, sound technical and practical training and experience, and should hold at least H.N.C. Men of mature experience and ingenuity only need apply. Good working conditions and prospects. Canteen facilities. Please write, giving age, qualifications, past experience, married/single, present salary to: Box No. 939, I.Prod.E., 10, Chesterfield Street, London, W.1.

Mechanical Engineer is required for a position in the engineering shops of a British concern in South India. Candidates must have served an apprenticeship and hold a recognised qualification, and preferably be single and under 30. Previous experience in a works supervisory capacity is essential. Initial remuneration will be not less than £1,000 per annum, in addition to which there is a Bonus Scheme, with, later, a graduation to a direct share in profits. Frequent paid home leaves with passages. Outfit allowance. Pension Scheme and Staff Provident Fund. Box No. 940, I.Prod.E., 10, Chesterfield Street, London, W.1.

Senior Time Study Engineer, required, with Institution membership or considerable mechanical experience. Minimum of five years on work and method study in engineering or process work. Knowledge of M.T.M. and Labour Cost Control desirable. This is a new appointment with a large firm of glass container manufacturers in the North-West area, and offers scope for advancement to applicants possessing necessary ability. Age 35 - 38. Appointment subject to medical examination. Reply, stating details of experience and salary required to: Box R.726, Lee & Nightingale, Liverpool.

Production Engineer required, by progressive engineering concern in their machine room, manufacturing small and medium components and machines. Applicants must have first class practical knowledge of modern tooling, latest production methods and ability to control progress on the most efficient and economic lines. Salary according to qualifications and experience, both of which will be necessary if applying for this vacancy. Box No. 941, I.Prod.E., 10, Chesterfield Street, London, W.1.

Senior and Assistant Development Engineers and Mechanical Draughtsmen. Racal Engineering Limited, invites applications from Senior and Assistant Development Engineers and Mechanical Draughtsmen, preferably with recognised professional qualifications, experienced in various aspects of the design of Airborne Radar Test Gear and H.F. communication equipments. Housing will be available to successful applicants after the completion of one month's probationary service, if at present residing in the Greater London area. Please forward in writing full details of experience, education, age, etc., to: Personnel Officer, Racal Engineering Ltd., Western Road, Bracknell, Berks.

Manager. A Manager is required to develop a group of sheltered industries on behalf of disabled people. His experience and his responsibilities will include the organisation of workshops and particularly to expand sales of the products. Salary, commensurate with ability and experience, over £750 with good prospects. Apply: Principal, Queen Elizabeth's Training College for the Disabled, Leatherhead.

Technical Assistants in Aircraft Production. Aircraft Manufacturers in greater London area, invite applications from energetic and ambitious men for vacancies as Technical Assistants on works management staffs. The following are essential requirements:-

1. Either (*a*) a good University Degree in Aeronautical or Mechanical Engineering, or (*b*) at least H.N.C. with a full Apprenticeship in aircraft or light engineering.
2. The personal qualities necessary for such appointments.

Initial salaries for superannuated positions will be commensurate with qualifications and experience. Write fully stating salary expected to: Box No. 942, I.Prod.E., 10, Chesterfield Street, London, W.1.

Production Engineer. Age 30 to 45, preferably with H.N.C. required to take full charge of Planning and Ratefixing Department in modern factory producing machine tools. Applicants must have had at least five years' experience of operational planning and ratefixing as applied to batch production of medium-weight components. Applications in writing to: Thomas White & Sons Ltd., Paisley.

Draughtsman, Plant Lay-out, required by Ultra Electric Ltd., Western Avenue, Acton, London, W.3. Previous experience is necessary, preferably in connection with mass production of electrical instruments. Progressive and permanent position. Pensionable. Good opportunity for the right man. Applicants are requested to write in strict confidence to the Personnel Manager for interview appointment, giving full details of age, experience and salary desired.

Cost Estimator required for mechanical and electrical equipment manufacturers. Applicants must be fully conversant with all modern production techniques, and capable of preparing cost estimates covering material, labour and tooling requirements. Apply: Personnel Manager, Ref. C.E., C.A.V. Limited, Warple Way, Acton, W.3.

Chief Planning Engineer. Applications are invited for the position of Chief Planning Engineer by well-known manufacturing electrical engineers in West London. Candidates must have sound experience of the following: Process planning for batch and mass production from raw material to finished assembly, time study and motion economy applied to light assembly work, factory lay-out for efficient batch and flow line production. Knowledge of press tool and fixture design an advantage. Candidates should hold high technical qualifications in Mechanical, Electrical and Production Engineering. Senior appointment carrying appropriate salary according to qualifications and experience. Write stating full details of experience and salary required to: Box No. 943, I.Prod.E., 10 Chesterfield Street, London, W.1.

Tool Designers. F. Perkins Limited, Peterborough, have a number of openings at their Bedworth, Coventry Office for Tool Designers for work on special purpose machine and fixture design. Preferred qualifications: full works apprenticeship, Ordinary National Certificate, tool and machine design experience, preferably in the automobile field. These are attractive and permanent positions, especially for young men in their twenties who are looking for further experience and prospects. Please apply in confidence, stating age, experience and education in chronological order to: Personnel Manager, F. Perkins Limited, Eastfield Factory, Peterborough.

ROCHESTER **7.30 p.m. DECEMBER 9th**
The Sun Hotel, Chatham.
"Shell Moulding" by M. C. Dixon, M.I.B.F. and R. S. Bushnell, A.M.I.B.F.

SHREWSBURY **9 p.m. to 1 a.m. DECEMBER 8th**
The Lion Hotel, Shrewsbury.
Annual Dinner and Dance. Dancing commencing from 9 p.m. to 1 a.m. to the Manhattans Dance Orchestra. Evening Dress or Dark Lounge Suit.

SOUTH ESSEX **7.30 p.m. DECEMBER 8th**
The Mid-Essex Technical College, Chelmsford.
"Shell Moulding" by M. C. Dixon, M.I.B.F. and R.S. Bushnell, A.M.I.B.F.

WEST WALES **7.30 p.m. DECEMBER 3rd**
The Central Library, Alexandra Road, Swansea.
"Planning for Production" by B. E. Stokes, A.M.I.Prod.E.

WOLVERHAMPTON **7.15 p.m. DECEMBER 1st**
The Wolverhampton & Staffordshire Technical College, Wulfruna Street, Wolverhampton.
"Control of Production as Applied to the Manufacture of Small I.C. Engines" by D. Dudfield, B.A. A.M.I.Prod.E.

WESTERN GRADUATE **7.30 p.m. DECEMBER 6th**
The Grand Hotel Broad Street, Bristol, 1.
"How much Management can we afford?" by Mrs. Ruby A. Ord.

PRODUCTION APPOINTMENTS

BULLETIN No. 50

This bulletin is circulated to all members of the Institution monthly as near as possible to the first of the month. Firms or organisations wishing to insert notices in the bulletin should communicate with the Secretary at 10, Chesterfield Street, London, W.1.

The last date for receiving material for insertion in the following month's bulletin is the 20th of each month.
The fee for insertion of particulars regarding each appointment is £3 3s. (up to 100 words), and over 100 words £5 5s. No charge is made to firms affiliated to the Institution, Technical Colleges, Universities and similar organisations.
Advertisers are advised that better response is likely if, in addition to essential qualifications, the following information is given :-
(*a*) Location of appointment; (*b*) Status in the organisation and scope of promotion; (*c*) Salary range and age range.
Advertisers are asked to advise the Institution when vacant appointments are filled. The Institution reserves the right to refuse or withdraw any announcement and also to make any alteration in the wording to ensure conformity with Institution standards.
Members interested in the following appointments should make application in accordance with the terms of notice. No correspondence can be undertaken by the Secretary other than the forwarding of replies to Box Nos.

All advertisements appearing in this Bulletin are subject to the Notification of Vacancies Order of 1952.

Chief Jig and Tool Designer. Sir W. G. Armstrong Whitworth Aircraft Limited, Baginton, Nr. Coventry, wish to appoint a Chief Jig and Tool Designer. Candidates must be over 30 years of age, and have completed a recognised engineering apprenticeship or similar course of training. Minimum technical qualification H.N.C. Airframe experience, including interchangeability media, advantageous. This is a senior staff appointment with permanency, excellent prospects and conditions and an attractive pension scheme. Write or call with full particulars to: the Personnel Manager.

Deputy Toolroom Superintendent. Hoover (Electric Motors) Limited, Cambuslang, Lanarkshire, have vacancy for Deputy Toolroom Superintendent. Applicants must have sound practical and administrative experience suitable for a large toolroom associated with light engineering. Range of work includes diecasting and progressive lamination tooling. Education of Higher National Certificate standard. Applications giving full details of qualifications for this position, should be made in writing to: the Employment Officer.

Civil Engineer, Mechanical Engineer, Production Engineer and Works Manager. An important organisation with interests throughout the British Isles and Commonwealth requires the services of a Civil Engineer, Mechanical Engineer and Works Manager. In each appointment proper qualifications and adequate executive experience are necessary. Age not over 45. Remuneration proposed is on the highest scale and there are good prospects. Full details of qualifications, post held and salaries to: Box 909, I.Prod.E., 10, Chesterfield Street, London, W.1.

Works Superintendent for dry battery factory in India having considerable engineering experience, thoroughly familiar with latest mass production methods and capable of assuring quality product. Apply by air mail giving full details of age, qualifications, experience and salary required to: Estrela Batteries, Limited, Post Box No. 6602, Bombay 19, (India.)

Draughtsmen, Senior Jig and Tool and Planning, required. Excellent opportunities exist of progressive advancement for men with initiative and ability to accept responsibility. Only applicants with these qualities are likely to be engaged. Young men with sound technical and practical engineering experience are also required. Must be over 24 years of age and will be considered for training in Planning and Jig and Tool activities. Good working conditions, with Staff Pension Fund. Sound teamwork is encouraged. Applications to be made in writing, stating experience, age and salary expected to: Personnel Superintendent, Morris Motors Limited, Tractor and Transmissions Branch, Wolseley Works, Drews Lane, Ward End, Birmingham, 8.

Production and Planning Engineer required by a progressive firm of Ironfounders and Engineers in London area, to be responsible to Works Manager for the control and direction of the production planning of the foundry, machine shops, progress, material control, buying and stores departments. Wide experience on these functions essential. Permanent position. Pension scheme. Please write stating age, education, engineering experience and qualifications, positions held and salary required to: Box No. 923, I.Prod.E., 10, Chesterfield Street, London, W.1.

Assistant General Manager for light engineering works. Sound theoretical knowledge, high educational standards, practical as well as administrative experience and cost consciousness essential. Public company with pension scheme offers excellent prospects for right applicant. Box No. 924, I.Prod.E., 10, Chesterfield Street, London, W.1.

Methods and Time Study Engineer. Successful Australian company which manufactures and markets household appliances and light engineering products with world recognition offers an executive position to control its methods and standards division. The company employs approximately 2,500 personnel. Applicants must possess the following qualifications :- (1) Age 30 to 40 years. (2) University degree in engineering or equivalent education. (3) Extensive knowledge and practical experience in methods engineering, motion and time study. (4) Experience must include the successful operation and control of financial incentive plans in light engineering industries. (5) Ability to plan, supervise and control the activities of the company's methods and standards department. Salary range will be £1,750 to £2,000 per annum depending on the

LIVERPOOL 7.30 p.m. NOVEMBER 17th
The Exchange Hotel, Liverpool.
"Shell Moulding" by D. N. Buttrey, M.Sc., A.R.I.C., A.P.I.

NORTH EASTERN 7 p.m. NOVEMBER 15th
The Neville Hall, Newcastle upon Tyne.
"The Practical Uses of Electronics in Industry" by K. A. Zandstra, A.M.I.E.E.

NORTH EASTERN GRADUATE SECTION 7 p.m. NOVEMBER 12th
Roadway House, 8, Oxford Street, Newcastle upon Tyne.
"Automatic Packing Machinery" by D. F. H. Rushton, M.A., Grad.I.Prod.E.

NORWICH 7.30 p.m. NOVEMBER 11th
The Assembly House, Theatre Street, Norwich.
"The Work of the Production Engineering Research Association" by Dr. D. F. Galloway, Wh.Sch., B.Sc.(Hons.), M.I.Mech.E., M.I.Prod.E.

NORTHERN IRELAND 7.30 p.m. NOVEMBER 11th
The Kensington Hotel, Belfast.
"Some Aspects of Work Study" by L. G. Humble, M.I.Prod.E.

NOTTINGHAM 7 p.m. NOVEMBER 2nd
Welbeck Hotel, Milton Street, Nottingham.
"Costing and Measurement of Productivity" by W. Coutts Donald, C.A., F.C.W.A. Joint meeting with the Institute of Cost and Works Accountants.

OXFORD 7.15 p.m. NOVEMBER 9th
The Town Hall, Oxford.
"Form in Design and its Influence on Productivity" by J. Beresford-Evans, M.S.I.A.

PETERBOROUGH 7.30 p.m. NOVEMBER 3rd
The Campbell Hotel, Bridge Street, Peterborough.
"Motion and Time Study" by Miss Anne G. Shaw, M.A., M.I.Prod.E.

PRESTON 7.15 p.m. NOVEMBER 10th
The Victoria & Station Hotel, Church Street, Preston.
"Resistance Welding Fabrication of Small Assemblies" by C. A. Burton, M.Inst.W.

READING 7.30 p.m. NOVEMBER 4th
Petters Ltd., Causeway Works, Staines, Middlesex.
"Recent Developments in Work Study" by N. A. Dudley, B.Sc.(Econ.) (Hons.).

ROCHESTER 7.30 p.m. NOVEMBER 11th
The Sun Hotel, Chatham.
"The Modern Tolerance System" by G. J. Pearmain.

SHEFFIELD 6.30 p.m. NOVEMBER 8th
The Grand Hotel, Sheffield.
"Boron Steels" by R. Wilcock.

SHEFFIELD 6.30 p.m. NOVEMBER 22nd
The Grand Hotel, Sheffield.
Informal Meeting.

SHEFFIELD GRADUATE 6.30 p.m. NOVEMBER 22nd
Royal Victoria Station Hotel, Sheffield.
"The Factory Inspector and the Production Engineer" by D. E. Jones.

SHREWSBURY 7.30 p.m. NOVEMBER 24th
The Shrewsbury Technical College, Shrewsbury.
"Patents and Registering a Design" by S. J. Parker, A.M.I.Prod.E. and "Human Safety in Engineering" by B. G. Williams, M.I.Prod.E.

SOUTHERN 7.15 p.m. NOVEMBER 18th
The Polygon Hotel, Southampton.
"Provocative Tooling Methods for Aircraft" by S. P. Woodley.

SOUTH ESSEX 7.30 p.m. NOVEMBER 10th
Ilford Bowling Club, Nr. Ilford Station, Essex.
"The Theory and Practice of Spark Machining" by A. H. Lines.

STOKE-ON-TRENT 7.15 p.m. NOVEMBER 15th
The Blue Room, Mechanics Institute, Crewe.
"Maintenance and the Production Engineer" by A. J. MacIntyre.

TEES-SIDE 7 p.m. NOVEMBER 23rd
The Darlington Technical College.
"The Technique and Application of Tungsten Carbide". Illustrated by films. By F. H. Bates, A.M.I.Prod.E.

WESTERN GRADUATE 7.30 p.m. NOVEMBER 8th
The Grand Hotel, Broad Street, Bristol.
"The Production, Fabrication and Properties of Titanium" by D. E. Yeomans.

WEST WALES 7.30 p.m. NOVEMBER 19th
The Central Library, Alexandra Road, Swansea.
"Designing for Production" by C. L. Boult, M.I.Mech.E., F.B.H.I.

WOLVERHAMPTON 7.15 p.m. NOVEMBER 3rd
Dudley & Staffordshire Technical College, Dudley.
"High Frequency Heating and Induction Hardening" by Dr. R. H. Barfield, D.Sc., M.I.E.E.

WOLVERHAMPTON GRADUATE 7.30 p.m. NOVEMBER 24th
The Wolverhampton & Staffordshire Technical College, Wulfruna Street, Wolverhampton.
"Some Impressions of a visit to America with a Productivity Team" by W. F. Garnham.

YORKSHIRE 7 p.m. NOVEMBER 8th
The Hotel Metropole, Leeds.
"Men and Machines" by J. E. Hill, M.I.Mech.E., M.I.Prod.E.

YORKSHIRE GRADUATE 2.30 p.m. NOVEMBER 6th
The Great Northern Hotel, Leeds.
"Education and The Production Engineer" by R. Shilton, M.I.Mech.E., A.M.I.Prod.E.

DECEMBER 1st to 9th, 1954.

COVENTRY GRADUATE 7.15 p.m. DECEMBER 7th
The Hare & Squirrel Hotel, Cow Lane, Coventry.
"The Application of Scientific Administrative Methods to Engineering Production" by C. Cooper, A.M.I.Prod.E., A.M.I.I.A., M.I.Ec.E.

DUNDEE DECEMBER 8th
Works visit to Messrs. Ferranti Ltd., Industrial Estate, Dundee.

GLOUCESTER & DISTRICT 7.15 p.m. DECEMBER 9th
The Cheltenham Motor Club, High Street, Cheltenham.
"Watch & Clock Production" by R. Lenoir, F.B.H.I. Joint Meeting with the Cheltenham Branch of the British Horological Institute.

HALIFAX 7.15 p.m. DECEMBER 1st
The George Hotel, Huddersfield.
"Production Panel"—composed of leading authorities from local industries.

HALIFAX GRADUATE 7.30 p.m. DECEMBER 9th
Collinson's Cafe, Crown Street, Halifax.
"A Scientific Approach to Management"—Open Discussion.

LEICESTER 7 p.m. DECEMBER 9th
The Balmoral Room, Bell Hotel, Leicester.
"Training as Related to Production Processes" by E. M. Price, M.I.Prod.E.

LIVERPOOL 7.30 p.m. DECEMBER 8th
Picton Hall, Liverpool.
"British Standards in Production Engineering" by Dr. E. L. Diamond, M.Sc., M.I.Mech.E., in conjunction with City of Liverpool Public Libraries.

LONDON DECEMBER 3rd
Dinner & Dance at the Savoy Hotel, London, W.C.2.

LUTON GRADUATE 8 p.m. DECEMBER 9th
Works visit to Thermoplastics Ltd., Dunstable, Beds.

MANCHESTER GRADUATE 7.15 p.m. DECEMBER 2nd
Reynolds Hall, (Room C.3), College of Technology, Sackville Street, Manchester, 1.
"The Electronic Control of Machine Tools" by E. Hey, A.M.I.E.E.

NORWICH 7.30 p.m. DECEMBER 3rd
The Assembly House, Theatre Street, Norwich.
"Planned Maintenance" by O. F. Lewis, M.I.Prod.E.

NORTHERN IRELAND 7.30 p.m. DECEMBER 2nd
Lecture Hall, Ulster Farmers Union, 18, Donegall Square East, Belfast.
"They're Everywhere". A G.K.N. film regarding nut and bolt production. Mr. Taylor of Short Bros. & Harland Ltd., will give a short talk on the subject after the film.

NOTTINGHAM 7 p.m. DECEMBER 1st
The Victoria Station Hotel, Milton Street, Nottingham.
"Work Study Techniques" by L. G. Humble, A.M.I.Prod.E.

PETERBOROUGH 7.30 p.m. DECEMBER 7th
The Campbell Hotel, Bridge Street, Peterborough.
"Precision Casting" by J. S. Turnbull.

READING 7.30 p.m. DECEMBER 9th
The Great Western Hotel, Reading.
"Copy Turning" by L. Lloyd.

Production Engineer. Venesta Limited require a Production Engineer for their factory engaged in production of collapsible tubes and similar impact extrusions. Applicants should have served a tool room apprenticeship and have experience of modern toolroom methods and tool design. The successful candidate will be responsible to the Production Manager for the tool room and engineering rather than administrative aspects of production. The commencing salary will be between £750 and £800 a year. Applications should be addressed to: the Personnel Manager, Venesta Limited, North Woolwich Road, E.16.

Planning Engineer, is required by a manufacturing company in the Acton, London, area, producing multiplicity of accurately machined components for internal combustion engines. Duties will be those of an engineering assistant in the Purchasing department. Experience in toolmaking, special purpose machines and drawing office is required, also sub-contracting with outside suppliers. Applicant, who should be 25 - 35 years should send details of age, previous experience, nationality at birth and salary envisaged, to: Box No. 944, I.Prod.E., 10, Chesterfield Street, London, W.1.

Works Manager (age 35-45) required by well-known aircraft manufacturing company, with several subsidiaries. Applicants should have had not less than 10 years' experience in the aircraft industry and be capable of assuming full control of the production engineering and manufacturing department. This position, which is a permanent appointment, offers excellent opportunities and an attractive salary will be paid to an applicant with the right qualifications and record. A pension scheme is available. Write, giving full details of experience, positions held, age and present salary, to: Box B.E.456, c/o 191 Gresham House, London, E.C.2.

Assistant Chief Inspector (age 35 - 45) required immediately by large aircraft company to take over full control as Chief Inspector within the next 12 months. Applicants must possess the requisite educational and training background to be competent to carry out full Ministry and A.I.D. procedure and to maintain the quality control of aircraft work in the highest class. The position is permanent and offers first-class opportunities to the selected applicant. A pension scheme is available and an attractive salary will be paid. Write, giving full details of experience, positions held, age and present salary to: Box B.E.457, c/o 191, Gresham House, London, E.C.2.

Methods Engineer, Production Engineer, Chief Ratefixer. Blackburn & General Aircraft Limited, invite applications for the following vacancies at their main factory at Brough:- **Methods Engineer** who will be responsible to the General Works Manager for the establishment of a Methods department to serve both the aircraft and engine divisions. Preference will be given to applicants with previous experience of new methods of manufacture and construction with an aircraft company. **Production Engineer** who will be responsible for the planning, progressing, ratefixing, jig and tool departments of the engine division covering both gas-turbines and reciprocating engines. Previous experience in similar capacity essential. **Chief Ratefixer** who will be responsible to the Production Engineer (Aircraft) for all ratefixing in the aircraft division. Age limits for each appointment 35/45 years. Good pension scheme and working conditions. The salaries will be commensurate with experience and qualifications, but will be attractive to the right applicants. Apply: Works Director, Blackburn & General Aircraft Ltd., Brough, E. Yorks.

EDUCATIONAL APPOINTMENTS

Loughborough College of Technology, Loughborough.
Senior Lecturer in Work Study.
Department of Industrial Engineering.
Applications are invited for two positions of Senior Lecturer in Work Study. One post has particular reference to Method Study, the other to Work Measurement. The persons appointed will assist in the development and conduct of courses, of both intensive and extensive types, and in planning the requisite laboratories. The college is residential and evening work is not normally involved. Applicants should possess a degree or suitable professional qualifications, and have had extensive industrial experience in Work Study, preferably including consultancy work. Salary will be paid according to the scale £1,065 - £25 - £1,215 per annum. Further details and forms of application may be obtained from The Registrar, Loughborough College of Technology, Loughborough, Leicestershire, to whom completed forms should be returned as soon as possible.

Hatfield Technical College, Herts.
Assistants Grade 'B'.
Owing to expansion of work in the College, the following vacancies arise. Successful candidates will be required to commence duties not later than ***1st January, 1955.*** **Technical and Design Engineering Department** (Ref. T/D). Assistant Grade 'B' in Electrical Engineering to teach Electrical Technology and Telecommunications up to Final Degree standards. Candidates should be graduates in Electrical Engineering, or possess equivalent professional qualifications, and have appropriate industrial experience. **Works and Production Engineering Department** (Ref. W/P). Assistant Grade 'B' to teach up to Higher National Certificate standard (Mechanical Engineering) and Final City and Guilds. Candidates should have had suitable industrial experience. Salary, Grade 'B' of the Burnham Technical Scale (1954), viz: £528 x £25 to £820 per annum, plus allowances for recognised qualification and approved industrial experience. Further particulars and application form obtainable from: The Registrar, Hatfield Technical College, Roe Green, Hatfield, Herts.

Brooklands County Technical College, Heath Road, Weybridge.
Assistant in Production Engineering (Grade A or B). Applications are invited for the post of Assistant in Production Engineering (Grade A or B). The work will be concerned with Ordinary National Certificate courses in Production Engineering to the City and Guilds of London Institute Trades courses requirements in allied subjects. It is intended eventually to develop the work to Higher National Certificate standard. Applicants should possess sound technological qualifications and good industrial experience. Teaching experience is desirable. Preference will be given to those with a knowledge of Machine Tools, Jigs and Fixtures, Metrology, Heat Treatment and Welding Practice. Salary Scale for men:- Assistant (B) — £525 x £25/20 - £820. Assistant (A) — £450 x £18 - £725 per annum. Assistants may receive additions to scale for approved qualifications and study. Commencing salary dependent upon previous teaching and other approved experience. Duties for this post will include some evening teaching. Application forms obtainable on receipt of stamped (2½d.) addressed envelope from the Principal, to whom they should be returned within 14 days of the appearance of this advertisement.

Hackney Technical College, Hackney.
Assistant Grade B to teach Mechanical Engineering subjects. Applications are invited as soon as possible for an Assistant Grade B to teach Mechanical Engineering subjects to Final City and Guilds Machine Shop Engineering standard and engineering drawing to S.2. O.N.C. standard, Ability to assist with classes for Motor Vehicle Service Mechanics, National Craftsmans Certificate an advantage. Salary within Burnham (F.E.) scale £561 - £982. Commencing and maximum salary according to qualifications and experience. Application forms from Secretary at College, Dalston Lane, E.8, for return by 12th November, 1954. (1357).

Coventry Technical College, Coventry.
Mechanical Engineering Department—Assistants Grade A *(3 vacancies)*
Required earliest possible following full-time teaching staff. Candidates should be graduates or hold good technical qualifications; previous teaching experience advantageous. *Mechanical Engineering Department*—Assistants Grade A (3 vacancies) — Applications considered from those experienced in some branch of Mech., Auto., Aero. or Production Engineering. *Mathematics Department* — Assistant Grade A—mainly for part-time Ordinary National Certificate and trades courses. Salary, Burnham Technical Scale (Grade A Assistants: £450 x £18 - £725). Application forms from Director of Education, Council House, Coventry, returnable without delay.

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